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VOL. II—DISCUSSIONS.

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INTRODUCTION.

IN publishing the proceedings of the Irrigation Conference held at Simla in September 1904, I desire to leave a few remarks on record for future guidance should another gathering of Canal Engineers be proposed.

On this occasion many of the papers were not received early enough, with the result that in several cases they were only placed in the hands of members on their arrival in Simla. Papers should be submitted so that they may be printed and circulated to members at least one month before they leave their stations for the Conference. This would give time to study the subjects of the papers and to collect, and note down, observations on them. The discussion was too conversational, it was difficult to record what was said and still more difficult to edit. Engineers in this country are not, as a rule, trained to speak on the spur of the moment. It may not be necessary to have recourse to set speeches, but it is advisable that those who intend to speak should attend armed with ample notes for ready reference.

I think it would be an advantage if a definite result of the discussion on each subject had been formulated and recorded, and I would do this in future.

In conclusion, I have only to express my regret that I have been unable to publish these notes earlier.

SIDNEY PRESTON.

CALCUTTA;
15th March 1905.

LIST OF MEMBERS AND VISITORS.

IMPERIAL SECRETARIAT.

S. PRESTON, C.I.E., A.M.I.C.E.	*Inspector General of Irrigation.*
E. G. STANLEY, A.M.I.C.E.	*Secretary to Conference.*

MADRAS.

J. P. DAVIDSON, A.M.I. C.E.	*Chief Engineer.*
A. T. MACKENZIE, M.I.C.E.	*Superintending Engineer.*
R. N. H. REID, A.M.I.C.E.	*Executive Engineer.*

BOMBAY.

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M. VISVESVARAYA, B.A., L.C.E., A.M.I.C.E.	*Executive Engineer.*
F. St. J. GEBBIE	*Executive Engineer.*

BENGAL.

G. C. MACONCHY	*Superintending Engineer.*
C. A. WHITE, M.I.C.E.	*Superintending Engineer.*
G. C. STAWELL	*Executive Engineer.*
P. G. JACOBS, A.M.I.C.E.	*Executive Engineer.*

UNITED PROVINCES.

H. MARSH, C.I.E., M.I.C.E.	*Chief Engineer.*
N. F. McLEOD	*Superintending Engineer.*
M. NETHERSOLE, A.M.I.C.E.	*Superintending Engineer.*

PUNJAB.

J. BENTON, C.I.E., F.C.H., M.I.C.E.	*Chief Engineer.*
R. G. KENNEDY	*Chief Engineer.*
H. V. S. BAKER	*Superintending Engineer.*
H. G. JOHNSTON, C.I.E.	*Executive Engineer.*
J. G. DAVIS	*Executive Engineer.*
F. C. ROSE	*Executive Engineer.*
F. E. KANTHACK	*Executive Engineer.*

RAJPUTANA.

G. G. WHITE, M.I.C.E.	*Superintending Engieecer.*
F. St. G. MANNERS-SMITH, K.I.H.	*Superintending Engineer.*

VISITORS.

General CASTEL BRANCO, R.E.	*Nova Goa.*
SYED JAFFER HOSSAIN	*Gwalior State.*
W. C. COOPER	*Punjab Public Works Department.*
F. F. BION	*United Provinces Public Works Department.*

LIST OF PAPERS PRESENTED AT THE CONFERENCE.

Monday morning, the 5th September.—

1. Mr. Mackenzie's paper on "Smart's Shutters."
2. Mr. Visvesvaraya's Description of the Bhatgarh Reservoir Gates.
3. Mr. Visvesvaraya's paper on Automatic Waste Weir Gate of Lake Fife.
4. Mr. Nethersole's paper on "Falling Shutters on the Paricha Weir."
5. Mr. Purves' paper on "Khanki Weir Shutters."

Monday afternoon.—

6. Mr. White's paper on Suction Dredgers.
7. Mr. Stawell's paper on "Sone Canals Head Works."
8. Mr. Marsh's paper on "Weirs in Rohilkhand."

9\. and 10. Mr. Hutton's paper on Financial Results of the Deoband Branch, Upper Ganges Canal, and Certain Drainage Cuts.

Tuesday morning, 6th September.—

11. Mr. Benton's paper on Silting Operations to Strengthen High Canal Banks.
12. Mr. Benton's paper on Syphon Proposed for Passing the Supply for Lower Bari Doab Canal under the Ravi.
13. Paper on the Thapangaing Aqueduct, Mandalay Canal.
14. Mr. Farrant's paper on Steel Tube Syphons, Swat River Canal.
15. Mr. Farrant's paper on the Design of the Suketar Superpassage, Upper Jhelum Canal Project.
16. Mr. Kennedy's notes on "Absorption Losses on Canals."

Tuesday afternoon.—

17. Mr. Hill's paper on "Earthen Dams."
18. Mr. Hill's paper on Proposed High Masonry Dam at Bhandardara.
19. Mr. McLeod's paper on Injury to the Narora Weir.
20. Mr. McLeod's paper on Failure of a Fall on Nadrai Escape.
21. Mr. Visvesvaraya's paper on A New Selfacting Module.

Thursday morning, 8th September.—

22. Mr. Reid's paper on Lift Irrigation.
23. Mr. Gebbie's paper on The System of Irrigation from the Jamrao Canal.
24. Mr. Morin's paper on River Training in Tanjore.
25. Mr. Maconchy's paper on "Flood Drainage."
26. Mr. Marsh's paper on Increase of torrent floods in the upper reaches of the Eastern Jumna Canal.

Thursday afternoon.—

27. Mr. Iven's paper on Mat Branch Extension, Ganges Canal.
28. Mr. Iven's paper on Injury to the Hindun Dam.
29. Mr. Marsh's paper on Automatic Puddling of Channels.
30. Mr. Kennedy's paper on Distribution of Water by Measurement.
31. Mr. Hill's paper on Distribution of Water in the Deccan.
32. Mr. Hill's paper on Deccan Irrigation Could be Made to Pay.
33. Mr. Hill's paper on Small Tanks in the Southern Mahratta Country.
34. Mr. Hill's paper on Nasik Bandhara Irrigation.

35. Mr. Kennedy's paper on Remodelling of Irrigation Distributaries.

36. Mr. Johnston's paper on Remedies Being Carried Out to the Siswan Superpassage, Sirhind Canal.

37. Mr. Kennedy's paper on Lessons to be Learnt from Sirhind Canal Silt Troubles with note by Mr. Gillmon on arrangement of gates at Rupar Head Regulator.

38. Mr. Kennedy's paper on value of " N " in Kutter's formula.

Friday afternoon.—

39. Mr. Visvesvaraya's paper on Economy of Water in the Deccan Irrigation.

40. Mr. McLeod's paper on the "Debarred Area" Scheme of the Fatehpur Branch.

41. Mr. Keeling's gate.

42. Mr. Leather's paper on Water of the Soil, (printed separately.)

IRRIGATION CONFERENCE, 1904.

The Honourable Sir A. T. Arundel, K.C.S.I., in opening the Conference said:—

I am not going to inflict upon you a long address, or to take any part in your discussions, but I should like to welcome you all here to this Conference, as experts in irrigation from all parts of India, and to express the hope and conviction that the meeting will be of great advantage to irrigation in future.

I think that for every branch of the administration it would be very much better if each Province were to know a great deal more than it does of what is going on in every other Province of India. Improvements may have been in force for years in one Province that are unknown in others, and it is possible that systems and methods that have become obsolete may still exist in other Provinces from want of information.

It seems to me that a meeting like this of yourselves, who are not only experts in irrigation, but enthusiasts in your profession, will be of very great benefit in future and will act as a great stimulus.

I anticipate further that subsequently by inter-communication by letter there will be an advantage not only to irrigation systems which have been constructed, but also to those which are under construction and in contemplation.

I only wish to again express my sincere hope and conviction that these conferences will be attended with great benefits in future.

I understand that Mr. Preston will preside to-day and that representatives from presidencies will preside on succeeding days.

I will now ask Mr. Preston to read a paper of a somewhat general character which will initiate the proceedings.

Introductory remarks by SIDNEY PRESTON, *Esq., C.I.E.*

You are, I think, all aware that the suggestion that a conference on irrigation matters should be held was made to me during a short tour which I was able to make in the Madras Presidency in February last, and I am glad to find that Mr. Mackenzie, from whom the idea emanated, has himself been able to be present.

I am in hopes that much good will come of the interchange of ideas; there is no intention of making these meetings annual occurrences, but in the course of a few years such further progress may have been made in irrigation science in some parts of India as will warrant a second conference.

I think it will be admitted that the papers which have been prepared cover a large range of irrigation practice. In arranging them for discussion I have endeavoured to group together papers of the same class so that we may not have to go through a series of mental gymnastics from one subject to another. We shall find that each Province has something to teach to the others, some invention, or practice, which is more or less peculiar to itself, and if the result of our meetings is that the good things of one Province become known to, and are copied by, the Engineers elsewhere the trouble you have all been put to in coming so far will have been more than repaid.

Thus the large gates, 40 feet span and 10 feet deep, described in Mr. Mackenzie's paper and a model of which is exhibited, are, as far as I am aware, peculiar to Madras; I discovered them during my tour this year and I am inclined to think that as a result of the conference we shall see them copied in the Punjab at least. Bombay has an extremely good form of automatic gate on the escapes of its large reservoirs. The Punjab has perhaps advanced most in the matter of water distribution by carrying a Government distributary to every village and in surveying, aligning, and in some cases constructing, the village watercourses to individual holdings. This has been already copied, and I dare say improved on, in Sind. The

United Provinces has erected some extremely efficient shutters on the top of the Betwa weir which has increased the storage capacity of the reservoir by 40 per cent. I do not propose to detain you with a long history of the present state of irrigation in India, but a brief account of the progress made in each Province during the last 35 years may not be out of place. I do not think that generally we have improved much on the grand works designed by Sir Proby Cautley in the United Provinces, by Colonel Dyas in the Punjab, or by Sir Arthur Cotton in Madras. Our canals are still modelled on the lines they laid down and the improvements made since have been mainly in details, and this leads me to throw out a suggestion which I hope may bear fruit; namely, that an endeavour be made in each Province to form a gallery of the portraits of the Engineers who have designed, constructed and developed the grand works which are now in our charge, but which, in due course, we shall have to hand over to others. I am glad to say this has already been done in both the Punjab and United Provinces, and I desire now to commend the suggestion to the Chief Engineers of Bengal, Madras and Bombay. I cannot but think that it must be of interest to our successors to be able to see what the men were like who initiated the great canals of the country; such as Rundall, Haig, Levinge, McNeile and Odling in Bengal; Fife, Merriman, Hughes, Whiting in Bombay, and Cotton, Anderson, Mullins and others in Madras.

Turning now to a brief review of the progress made in each Province since the year 1869-70—I have chosen this period as it corresponds with my own personal experience.

In that year the major canals in Madras comprised the following systems:—(i) the Godavari delta, (ii) Kistna, (iii) Penner and (iv) the Cauvery delta. The capital expended on them amounted to Rs. 1,35,71,133, they irrigated 1,662,539 acres and paid 17·28 per cent. To these the Srivaikantam project was added in 1870-71; the Kurnool-Kuddapah in 1882-83; the Barur tank in 1888-89; the Rushikulya in 1893-94 and the Periyar in 1896-97. At the end of 1902-03, the last year for which I have complete figures, the capital invested had increased to Rs. 7,46,77,598, the area irrigated to 2,940,953 acres while, although the percentage of profit had decreased to 8·7 per cent. the works as a whole gave a net revenue of Rs. 64,96,356 to the State.

The minor works comprised 10 projects, irrigated 267,922 acres and earned a net revenue of Rs. 2,17,551. There are now 23 minor irrigation schemes in operation which irrigate 584,081 acres and yield a net revenue of Rs. 7,39,020.

In 1869-70 the major canals in operation in Sind were the Desert, Begari and Eastern Nara; they cost Rs. 30,34,812, irrigated about 200,000 acres and gave a net revenue of Rs. 1,12,122. They now comprise the Desert, Unharwah, Begari, Eastern Nara, Jamrao, Dad and the Mahiwah; they irrigated 1,072,001 acres in 1902-03, cost Rs. 2,27,38,960 and earned a net revenue of Rs. 11,43,217 equivalent to 5·03 per cent. on the capital outlay. Besides these works an expenditure of Rs. 12,02,899 has been incurred on the Naulakhi and Nasrat canals still under construction.

The minor works in Sind comprised two projects, irrigated 233,953 acres and gave a net revenue to Government of Rs. 4,32,969. There are now 7 minor works in operation which irrigate 794,530 acres and yield a net revenue of Rs. 8,53,684.

In 1869-70 the Major Canals in operation in Deccan and Gujarat were the Wadali canal of Kadva river system, Lakh canal and Krishna canal. They cost Rs. 10,64,345, irrigated about 1,043 acres, but the working expenses exceeded the revenue by the sum of Rs. 16,793.

They now comprise (i) the Nira canal, (ii) Shetphal tank, (iii) Mhaswad tank, (iv) Hathmati canal, (v) Lower Panjhra river works, (vi) Kadva river works, (vii) Lakh canal, (viii) Mutha canals, (ix) Ekruk tank and (x) Krishna canal. These works irrigated 62,258 acres in 1902-1903, cost Rs. 1,96,36,551 and earned a net revenue of Rs. 3,78,740, equivalent to 1·90 per cent. on the capital outlay.

The minor works comprised nine projects, irrigated 1,309 acres and cost Government a net loss of Rs. 14,686. There are now 26 minor works in operation which irrigate 38,237 acres and yield a net revenue of Rs. 27,728, or 0·36 per cent. on capital outlay.

In Bengal the only irrigation works in operation in 1869-70 were (*i*) Kendraparah, (*ii*) the High Level and (*iii*) the Taldunda canals in Orissa, which together irrigated 14,740 acres, and the Midnapur canal in Bengal proper which irrigated 14,792 acres. The Orissa canals now irrigate 224,998 acres and the Midnapur 87,464 acres. In 1875-76 the Sone canals were opened and irrigated 41,670 acres which has increased to 483,567 acres in 1902-1903. The capital cost of the canals, including the Hijili Tidal canal, which is a purely navigation canal, has increased from Rs. 1,40,17,891 to Rs. 6,43,54,346, and the net revenue credited to the State from Rs. 3,718 to Rs. 9,64,672. Amongst the class of Minor Works the Sarun canals commenced irrigation in June 1880 doing 3,287 acres in that year, but the development has been small as in 1902-1903, they only did 4,411 acres. The Eden canal was opened in 1889-90, irrigating 9,693 acres in that year, which has increased to 27,767 in 1902-1903. If the canals in this Province have not proved as directly remunerative as those elsewhere, it is more due to local circumstances than to the fault of those who initiated them. They have undoubtedly done much to protect the Province in years of bad rainfall.

In the United Provinces, or the North-Western Provinces as it was then called, the Major Canals in operation in 1869-70 were (i) the Upper Ganges and (ii) the Eastern Jumna, while the Minor Works comprised (i) the Dun, (ii) Rohilkhand, (iii) Bijnur canals and certain lakes in Hamirpur and Jhansi. Rs. 2,71,36,402 had been expended on the Major Works and Rs. 12,37,061 on the Minor; the former irrigated 1,031,473 acres, earned a net revenue of Rs. 24,09,147 equivalent to 9·21 per cent. on the capital cost. The latter irrigated 58,200 acres and earned a net revenue of Rs. 23,664. Thus in the year 1869-70 the irrigation works of the Province matured 1,089,673 acres of crops. In 1874-75 the Agra canal was opened, irrigating 15,126 acres in that year; this was followed by the Lower Ganges canal in 1877-78; the Betwa (protective) scheme in 1885-86 and the Fatehpur Branch of the Lower Ganges canal in 1898-99.

These increased the capital invested on Major Works at the end of 1902-03 to Rs. 8,88,92,908, but the area irrigated increased during the same period to 2,306,180 acres and the net revenue credited to the State to Rs. 62,23,486, giving a return of 7 per cent. No new Minor Works have been added to those in operation in 1869-70, but the capital invested has increased to Rs. 31,69,546, and the area irrigated to 137,375 acres, but the net revenue is still small amounting in 1902-03 to Rs. 87,605.

The greatest developments have naturally been in the Punjab, with which in this review I will include the North-West Frontier Province, mainly because it was the last to begin operations. But if its canals have been phenomenally successful, it is as much due to its natural advantages as to the skill of its Engineers. A Province which owns immense areas of flat fertile land, six large rivers with perennial supplies and a small rainfall engendering a continual demand, was bound to make rapid progress when operations were once started.

The Major Works in operation in 1869-70 were (i) the Western Jumna and (ii) the Bari Doab canals, while in the class of Minor Works were the Upper and Lower Sutlej Inundation canals, those from the Indus and Chenab and some small tanks in Delhi and Gurgaon.

Rupees 1,56,77,478 had been invested in the Major Works, they irrigated 730,470 acres and earned a net revenue of Rs. 17,26,078, or 11·08 per cent. on capital outlay. The Minor Works irrigated 530,940 acres and gave a net sum of Rs. 1,87,164 to the State.

The following additions have been made to the Major Works. In 1882-83 the Sirhind canal was opened, in 1884-85 the Lower Sohag and Para canals, in 1885-86 the Swat River; in 1886-87 the Sidhnai canal; in 1887-88 the Chenab canal as an inundation system which was converted into a perennial one and

large extensions commenced in 1892-93; in 1890-91 several subsidiary canals from the Ravi river in connection with the Sidhnai; in 1891-92 the Sirsa Branch of the Western Jumna canal and in 1901-02 the Jhelum canal. The ten years from 1891-92 to 1901-1902 were occupied in extending the Chenab and in the construction of the Jhelum canals. All these schemes and numerous extensions of the older ones increased the total capital expenditure at the end of 1902-1903 to Rs. 12,28,63,973, in which year the area irrigated amounted to 5,038,046 acres and the net revenue to Rs. 1,32,26,027, giving a return on capital of 10·76 per cent.

During the same period very considerable additions were made to the Minor Works in charge of the Canal Engineers. In 1880-81 the Muzaffargarh Inundation canals were taken over from the Civil officers; these were followed by the Hajiwah in 1888-89, the Shahpur (Provincial) canals in 1894-95; Kabul River canal in 1898-99; the Rangoi canal in 1901-1902 and the Ravi Inundation canals in 1903-1904. In 1870-71 a series of Inundation canals in the Shahpur district were purchased by the Imperial Government and the Ghaggar canals were opened in 1897-1898. These and considerable improvements in all the systems increased the capital expenditure on Minor Works at end of 1902-1903 to Rs. 17,80,452, in which year those for which capital and revenue accounts are kept irrigated 235,087 acres and brought in a net revenue of Rs. 2,13,993.

There remains the Province of Burma. In 1869-70 the amount invested in Provincial minor irrigation works amounted to Rs. 14,04,930; this had increased at the end of 1902-1903 to Rs. 34,53,416. Complete statistics of the area benefitted are not available before 1891-92, but in that year 612,700 acres were benefitted mainly by the embankments which kept back disastrous floods. In 1902-1903 this had increased to 845,020 acres. Three major canals are now under construction and in 1902-1903 the Mandalay canal did 7,223 acres of irrigation.

As the result of the recent famines in the Central Provinces the Government of India have sanctioned the construction of a number of reservoirs and many more are in contemplation, and that Administration will soon be added to the list of irrigating provinces in India.

The progress made in the last 35 years in developing irrigation may then be summarized as follows.

30 new Major Works have been constructed and opened. The capital invested has increased from Rs. 7,44,02,061 to Rs. 39,78,61,100, the area irrigated from 3,655,057 acres to 12,222,690 acres.

The area irrigated by Minor Works of all kinds has increased from about 4,000,000 acres to 7,578,583 acres, so that during the year 1902-1903 the Government irrigation works irrigated the large area of 19,801,273 acres.

I will not refer to the future: there are still some large works to carry out in Madras, the Punjab and Sind and numerous smaller ones in other provinces, and I envy the younger members of our profession who will have the charge of them and who, in another 15 or 20 years, will be able to record a vast increase in the area irrigated in this country.

The papers set down for discussion on Monday morning were as follows:—

1. Mr. Mackenzie's paper on "Smart's Shutters."
2. Mr. Visvesvaraya's Description of the Bhatgarh Reservoir Gates.
3. Mr. Visvesvaraya's paper on Automatic Waste Weir Gate of Lake Fife.
4. Mr. Nethersole's paper on "Falling Shutters on the Paricha Weir."
5. Mr. Purves' paper on "Khanki Weir Shutters."

Mr. Preston, who presided in opening the discussion, said the papers divided themselves in two groups—

(1) gates suitable for escape weirs;

(2) gate suitable for rivers either on a raised weir or in place of a weir.

The Bhatghar and Lake Fife automatic gates were examples of the former while the Paricha, Khanki and Smart's shutters were instances of the latter.

Extremely good working models of all these were exhibited and photographs of these are reproduced. Some time was spent in demonstrating the working and in conversation round them. Mr. Preston drew attention to the enormous surplus power provided by the Madras Engineers in connection with the socalled Smart's shutter; not only is the shutter fully counterbalanced, so that there is nothing to overcome, but friction, yet a quadruple purchase winch has been provided.

Mr. Davidson explained that as the shutter had to go down by its own weight, it is necessary to lift the counter weight; this was admitted but as these weights are only 14 tons each it does not seem necessary to have such powerful winches and it seems possible the cost might be reduced.

Mr. Preston invited attention to the large span of these shutters, *viz.*, 40 feet, which was he believed the largest in India although he understood Mr. Mackenzie has visions of 80-foot spans in connection with the Tungabhadra project. Mr. Preston thought it was a matter for consideration and discussion as to what the practical and economical limits were. Mr. Mackenzie was asked to state the advantage of an 80-foot span. He did not think that in a matter of this kind economy was a matter for serious consideration: the difference in cost would be a bagatelle in such large works, he thought it would be easier to work a regulator with 80-foot shutters as there would be half the number of gearings, etc.

Mr. Marsh objected to these large spans as there is no second line of defence in case of anything going wrong with the shutter or gearing. He said that in all the old works with small openings it had been usual to provide one or two sets of grooves up and down stream of the shutter in which planks, backed by earth, could be placed in case of any accident to the gate, or it is possible to place baulks of timber across the upstream noses of the piers. He pointed out that with these large spans any of these devices would be impossible and he asked what would be done if the gate got jammed and would not go up or down as required. It was admitted by the Madras Engineers that nothing could be done but cut the chains, if the shutter was up, and to let it drop, it was thought it would be unlikely to get jammed as the recess in which it works is a wide one. Mr. Marsh was not satisfied and thought some second line of defence should be devised; he had known instances in the United Provinces in which gates had got jammed and in which hopeless damage would have been done if there had not been a second line of defence.

Mr. Preston thought that some means of getting the shutters up or down would certainly be found by the Engineer in charge; these large spans had been in use in Madras for 3 or 4 years and no instance had yet occurred in which there had been difficulty in working them. Mr. Davidson had said they had given the Engineers complete control over the regulation of the Tanjore delta and they undoubtedly gave immense command over the river as having no raised weir it is possible to scour deposits from the river anywhere.

Mr. Preston invited attention to the great difference between the coarseness of the sand in the Madras delta and that found in the rivers of the Punjab and United Provinces and he had the specimens of the sand from most of the rivers in India, which were collected by Mr. Spring when writing his monograph on river training, produced for inspection. He pointed out that the sand of the Madras river was like boulders compared with that of the upcountry rivers and this would have to be taken into consideration in comparing the cost of a barrage of the Madras type with that of a weir with falling shutters. He was much struck in visiting the Madras works at the small amount of protection which was found necessary up and down stream of the works and this was largely due to the much coarser material in the beds of the rivers. The Madras Engineers were much to be congratulated in having such material to found in. Mr. Preston thought it would be of great interest, if the Madras Engineers would state the cost of their barrage with large shutters per foot run, or per span, so that upcountry men could compare it with that of a raised weir with falling shutters and undersluices; of course the latter would have to make allowance for the different foundations which would be necessary due to the difference in the quality of the sand of the river bed already alluded to

Mr. Davidson undertook to obtain this information and to forward it to the Secretary to the Conference and at the same time to afford a little more detail than was given in the paper as to the weight of the shutters and counter-weights. He also undertook to compare the costs of shutters with Stoney's antifriction roller frames with the alternative known as "Smarts" shutters. Every one agreed as to the great advantage of the former, but the cost of them had been somewhat prohibitive in ordinary cases owing to the high royalties charged by Messrs. Ransome and Rapier. Their patents have expired and as there is now nothing to prevent Stoney's system being made up in Government shops, the cost could be greatly reduced. It was stated that the Smart's shutters 40 feet span cost Rs. 30 per square foot against Rs. 49 for Stoney's system at Ransome and Rapier's prices.

Mr. Mackenzie in reply to several questions said he believed that the biggest spans will be found to give the maximum economy because of the smaller obstruction of the river. That they had not yet succeeded in finding a satisfactory paint for the ironwork, bituminous or other. He was asked whether the [illegible]" plates which formed the skin of the shutter were used to give weight to carry it down and whether this would be reduced to say $\frac{1}{4}$" if Stoney's rollers giving less friction were used; in reply he said the [illegible]" skin had been used as thinner plates were found to get bent in transit.

Referring to the paper and model of the shutter erected on the Paricha weir Mr. Marsh said they had worked extremely well the only trouble had been that the bracing of the gates is not quite strong enough, but in other respects they had been a great success.

A good deal of time at this sitting was taken up by a discussion raised by Mr. C. A. White as to the form of shutter that would be most suitable in the peculiar circumstances of the Dhaka weir in Bengal. There was nothing in the conversation that ensued of interest for this record as the members of the Conference were insufficiently acquainted with the local circumstances to form an opinion on the spur of the moment. The conversation, however, occupied some time and somewhat crowded out of consideration the Bhatghar and Lake Fife automatic gates, although, after the sitting was over, much interesting conversation followed amongst members over the models.

With reference to Mr. Preston's remarks above Mr. Davidson has since stated that the cost of Smart's shutters of different depths and spans with gearing and counterweights including carriage to and fitting at site varies from Rs. 22 to Rs. 30 per square foot of shutter and that Rs. 25 may be assumed as a fair average. He has compared the relative cost of a barrage with Smart's shutters and a solid weir such as was previously built in Madras for 3 or 4 cases and finds that the barrage would in practice be twice as expensive as the solid weir. If Stoney's shutters were used, the difference would be even greater.

Regarding the greater efficiency of the barrage, he writes as follows :—

Admitting this difference of cost and accepting it, the question arises is there any reason why the relative cost should be compared? The two works are essentially different in their action, and for our purposes the barrage is twice as efficient. This efficiency you must pay for. With our body-wall weirs and our heavy sand; in spite of sand sluices with sills at levels lower than the sills of the canal head sluices; the head sluices draw off immense quantities of sand and as the velocity in the channel checks (the channel velocity is of course less than the river velocity), the sand deposits with the result that the discharge of the channel is reduced by as much as possibly 50 per cent. and may for a time be reduced to nothing. This sand filling has to be cleared out frequently. Even with raised sills to the sluices the body-wall obstruction is sufficiently great to result in large masses of sand getting over these raised sills.

With the shutter work there is no obstruction, and if the sluices have raised sills the river itself has a greater draw than the head sluices and the sand (heavy sand) which travels low down follows the line of least resistance and goes down the river-bed instead of into the canals.

I am of opinion that there is no use in comparing cost of solid body-wall weir with shutters; if the latter work will do all that is required in any particular case, then adopt it: but if the shuttered work with its increased efficiency is necessary, it is worth paying the extra cost. Against this extra cost there would be savings in many recurring annual charges, which would give a reasonable percentage on the increased outlay. There would be upkeep of spurs and embankments and frequent clearance of canal beds of sand deposit.

MONDAY AFTERNOON.

The papers set down for consideration were—

6. Mr. White's on "Suction Dredgers."

7. Mr. Stawell's on "Sone Canal Head Works."

8. Mr. Marsh's on "Weirs in Rohilkhand."

9. & 10. Mr. Hutton's on the Financial Results of the Deoband Branch, Upper Ganges Canal and of certain Drainage Cuts.

Mr. C. A. White, who presided, in introducing his paper suggested that its subject "*Suction Dredging*" is of the very greatest importance for the prosperity and advancement of India, and Suction Dredging should be universally adopted in India. On the second page of the paper he detailed four different works for which it is suitable.

He said as regards Harbours, that a few months ago returning from England he was kept waiting outside the bar at Karachi for want of water. Inside he saw a few bucket dredgers raising their 1,000 cubic feet an hour or less. Karachi is an excellent place for Suction Dredging and land reclamation, either on the system so successfully adopted in Antwerp, as illustrated in the paper, or by Mr. Darley's system of dumping it in some suitable place, and pumping it thence on to the land to be reclaimed as is practised in New South Wales.

Any one who has been to Karachi knows there are large swamps round the harbour and docks which would be valuable building ground if reclaimed.

The particular points on which he invited discussion are noted at the bottom of page 2 of the paper, and are as follows:—

(*a*) the best type of dredger to cut a channel 5 miles long with 100 feet base, 5 to 10 feet depth, in a river like the Bhagirathi, which is, say, half a mile broad, with depth of water varying from 3 to 25 feet, and velocity from 1 to 5 miles an hour;

(*b*) the best means of disposing of the soil;

(*c*) the best means of handling the dredgers;

(*d*) the number of suction pipes and nozzles to be used for cutting the channel mentioned above to a fairly level bed.

Continuing Mr. White said, you are no doubt aware the Bhagirathi is the river connecting the Ganges and the Hooghly and is the direct river route to Calcutta from upcountry. Government is anxious to open up this channel which has deteriorated, and proposes to obtain a large Suction Dredger for the purpose.

No discussion followed these remarks, as the subject is one on which canal Engineers in India have had no practical experience. It was generally considered that the paper was interesting as bringing the subject to their notice, but owing to the cheapness of labour in India the great proportion of the canal clearance work is effected by coolies when the canals are closed.

The meeting then proceeded to the consideration of Mr. Stawell's paper.

Mr. White said—It is very interesting to hear that Mr. Buckley has successfully introduced the system of hydraulic gear for releasing the undersluices of the Sone Head Works, a system he so strongly advocated for India when he read a* paper before the Institution of Civil Engineers in 1880 on "Moveable dams in Indian weirs," a copy of which can be found in the "Professional papers on Indian Engineering" dated April 1880.

† A more elaborate system than that described in this paper was invented by Mr. Girard in 1869 for regulating a navigation weir at Ile Brulée on the Yonne River by which any shutter ($11\frac{1}{2}'$ long by $6'$ high) can be raised or lowered at will.

* *Vide*—Minutes of Proceeding I. C. E. Vol. LX. (Paper No. 1670).
† *Vide*—Rivers and Canals by L. F. Vernon-Harcourt page 120, Edition of 1882.

Hydraulic power must give a much greater control over the weir than any other means, obviously the next thing to be done for the Sone weir is to provide hydraulic power for raising the undersluice gates when funds become available.

He suggested that more control could be obtained over the crest shutters if the tie rods were fixed at different heights, so that the shutters fell with different heights of water. This was successfully done for Midnapur weir and also to the shutters of the Paricha weir.

The concluding remark of Mr. Stawell's paper is an important one, it reads—

> "The improvements described above are due to Mr. R. B. Buckley, late Chief Engineer of Bengal. They have given more control in the working of the weir and enable a fairly constant head being kept in the river to meet the demand for irrigation; the only thing now needed being some means whereby the crest shutters of the weir itself can be controlled and some method of lifting the lower undersluice gates or assisting the manual labour now employed to pull them up. Some system of scouring pipes is also require to clear away the sand and silt that collects in front of the upper gate when it is raised and which has to be cleared away by divers before the gate can be laid down."

It has several times been proposed to close the centre sluices of the Madanuddy weir, Mr. Rhind was opposed to it. The speaker revived the idea a few years ago, but believed the proposal was again negatived.

An Engineer held up, as an argument against closing the centre sluices, the evil results that had happened from closing those of the Sone weir, saying that the result was that when a flood came, the pool in the river bed down-stream was not filled quickly enough, so that a standing wave was formed at the bottom of the apron, which broke up the pitching.

Mr. Stawell can doubtless say if there is anything in this objection, and also if closing the centre sluice has caused any increase in the height of the flood, he mentions that it has increased the duration.

Mr. Stawell in reply said—On the Sone Canals system the most important time is the kharif irrigation for the rice crop; a time when the river is most liable to heavy floods.

From observations made it has been decided that in order to keep silt out of the canal and to avoid an excessive expenditure on dredging it is advisable to keep the undersluice gates up as long as possible and that, when the flood necessitates all the undersluices being dropped, the canal head should be entirely closed and kept closed until, at least, five of the undersluices have been again raised.

To avoid any undue strain on the undersluices and on the chains holding up the gates the shutters on the weir are dropped when the river rises in flood to a level of 10·50 on the gauge.

The retention of the shutters until the flood reaches this level has been rendered possible by the hydraulic gear of the undersluices. Whether they could be left up without risk for a higher stage of the river has not yet been decided. The experiment is risky as the whole of the undersluices might be carried away as has happened once before; or the weir shutters themselves might be badly damaged if more than about 6″ of water was allowed to fall over them. There is also the difficulty of getting at any particular shutter on the weir if anything went wrong with its releasing gear, should a considerable depth of water be flowing over the top of it. It would be almost impossible to get out the movable foot bridge, which is the only means of getting at any individual shutter. The raising of the undersluice gates is a difficulty. At present only 4, or at the most 6, can be raised in a day owing to the sand that accumulates when the advance gate is raised, this prevents it being laid down flat on the floor till the sand has been cleared away; this has to be done by men diving down and clearing it with their hands.

The needle weir admits of the undersluice gates being raised at a higher stage of the river than formerly, but the higher the river level the greater the

quantity of sand deposited when the front gate is got up and therefore the greater the delay in getting up any number of gates. This contrivance is therefore, practically, very seldom used and only in cases when there is a great demand and there has been a fairly long closure of the canals.

It is also advisable not to lift the front gate at too high a stage of the river for fear of damaging it by the shock. This, even with the needle weir, is considerable with a high gauge: and there is still danger of the hydraulic rams being driven through the gates, as has happened, although it is much less than it used to be.

The crest shutters on the weir can only be used to keep up the level of the river after the undersluice gates have been raised. To lift them first would not mend matters at all as they would only tend to raise the level of the river and delay the raising of the undersluice gates and the opening of the canal. If the canal is opened before some of the undersluice gates are up the head reach becomes choked with silt and if some of them have to be got up, it is as well to get all up before raising the crest shutters.

The difficulty with the sand, which prevents the undersluice gates being raised rapidly, can only be overcome by introducing some system whereby the deposit can be scoured out and carried down below the weir. Mr. White had suggested that more control could be obtained over the crest shutters if the suspension rods were fixed at different heights. This has to a certain extent been done, and has been fairly successful. The difficulty, however, is to fix the rods so that the shutter will fall at a reasonable height of flood and avoid any pounding on, and damage to, the weir packing due to water falling over the top of the shutters.

Regarding the effect of closing the centre sluices it is hard to say anything definite. There is no doubt that the duration of floods has been increased; but there are no records available to show what increase has been made in the height of flood above the weir.

One of the objects of the centre sluices was to fill up the pool below the weir and prevent damage to the toe of the slope. In 1903 there were three breaks in the weir slope. This was due probably to the low floods not having filled up the lower pool and the standing wave acting on the toe instead of, as was formerly the case on the slope, this would induce a scour, with the result that the toe eventually gave way. In 1904 the toe was extended in order to prevent this action as far as possible.

It does not seem that the application of hydraulic power is possible to raise the undersluice gates. The force to be employed to overcome the resistance of the water going through the undersluice vents would be enormous and the shutter would have to be extremely strong to resist it.

Mr. Stawell would have a shutter on the weir crest over which there would be perfect control and which could easily be lifted against a head of 2 feet; the length of the Sone weir is against any of the present patterns in use on other weirs. Hydraulic power could be utilized for this, but the expense would be great and would entail a good deal of alteration to the weir itself.

Referring to the paper by Mr. Marsh on weirs in Rohilkhand, Mr. White circulated plans showing the sites proposed for two weirs across the rivers, Bagrathi and Kumla in North Behar. He said the conditions of both are very similar, the lands to be irrigated are subject to famine and lie along the Nepaul Frontier, for this reason the weirs must be placed as close as possible to the boundary, there are also other limitations which fix the site of the weirs and prevent their being built further away from the frontier.

In both cases the main river is at present running along the bank opposite to that on which the canal will take out; in the case of the Bagrathi there is some room above the weir on the right where training works can be constructed to force the main channel over to the left bank from which the canal will take off. But in the case of the Kumla the only way to bring the river to the head sluice appears to be by damming the river above and making a cut thence across to the undersluices. As against the probable success of this scheme it may be noted that at the head sluice of the Western Jumna Canal it has

been found that undersluices are powerless to influence the current of the river for any great distance of stream and it is sometimes necessary in the cold weather to make a cut through the heavy shingle deposits above the weir to lead the water of the river to the head sluice. Also on the Upper Coleroon in Madras although the undersluices are one-twelfth of the whole weir yet the weir channel above silts up. A railway is contemplated near the Bagrathi weir and a bridge will be required a little lower down, hence the suggestion has been made that as the sites were so limited a combined railway bridge and weir might be constructed, no such conjunction was known to be in actual existence in this country, but it was considered that it would be quite feasible.

Mr. Preston said that in his opinion it would be better in the case of the Kumla project to force the river back into its old channel along the eastern bank if the Nepaul Durbar would agree. If it would not, he would accept the conditions as they exist, extend the canal across the old silted up channel and build the head works on the existing river channel even though the foundations would be in sand instead of in clay. None of the members of the Conference knew of an instance of a railway bridge being combined with a weir, but several thought there would be no objection if any advantage would be gained by it.

The papers by Mr. Hutton are interesting as a record of works which were successful from a revenue point of view, but these subjects did not lend themselves to discussion.

TUESDAY MORNING.

The papers set down for this sitting were as follows:—

11. Mr. Benton's on Silting Operations to Strengthen High Canal Banks.
12. Mr. Benton's on Proposed Syphon for Passing the Lower Bari Doab Canal Under the Ravi River.
13. On Thapangaing Aqueduct, Mandalay Canal.
14. Mr. Farrant's on Steel Tube Syphon, Swat River Canal.
15. Mr. Farrant's on Proposed Sukefar Superpassage, Upper Jhelum Canal Project.
16. Mr. Kennedy's notes on "Absorption Losses on Canals."

Mr. Benton, who presided, called on Mr. Kennedy to open the discussion. The latter said he thought definite rules should be issued that in all new schemes the banks should be set back as proposed by Mr. Benton wherever there is likely to be any danger of breaching. As to how much this should be, the best criterion appears to be the inclination of a line joining the outer toe of the bank with the edge of the water surface, after the inside silting is completed. By roughly drawing out various sections, he arrived at the conclusion that this inclination should be *not less* than one in six and in special cases should be more.

There are however still many cases on the older canals where it is too late to use internal silting, and sooner or later it will be necessary to have recourse to the "Long Reach" system, where the whole canal is turned into outside reaches. Cases are very frequent where outer banks have been made up for this purpose, but owing to their being too near the inner banks to carry the whole supply, they have never been used, and if they had been, there would have been no silt deposited from the velocity being too great.

In such cases also definite instructions are required, and in order to arrive at these, we must assume that the final silting of bed of these outer reaches will reach a certain depth below full supply level. For whatever period these silting reaches are allowed to go on working, a limit of deposit would eventually be reached, fixed by the increase in the velocity of flow as the bed silted; and ultimately the limiting depth of the water would be such, with the given discharge and bed width, that the critical velocity (Vo of Kennedy's diagrams) for that depth would be obtained. Now it is known from experience what these critical mean velocities are for various depths, and it will therefore be quite simple to make out a rule for the width of these long outside reaches; once it is decided to what depth, below full supply level, silting is to take place. Mr. Kennedy suggested that for small channels this might be 2·0 feet, and for large canals, where the cost of outside land was high, it might be 3·0 feet.

Then Let D = Discharge.

B = Bed width of outer reach.

For a depth of 2·0 feet Vo = 1·3, and for 3·0 feet depth Vo = 1·7; then we have the following:—

For silting up to 2 feet below full supply level $D = 2B \times 1·3$ or $B = \frac{D}{2·6}$

Ditto 3 feet ditto $D = 3B \times 1·7$ or $B = \frac{D}{5·1}$

The widths B, thus deduced, are really the average widths of flow in the outer reaches in the final stages, *i.e.*, just below full supply level, or roughly the width between the outer and inner banks just below the water line. The last foot or so of silt would be deposited very slowly, and if it is desired to complete up to the 2 feet or 3 feet limits in reasonable time, and without having recourse to the wasteful system of "in and out" reaches, a greater breadth —B— than the above expressions allow must be given. Assuming that instead of waiting till Vo is reached, it is stopped when 0·80 Vo obtains, then the above values of B would be—

for 2·0 feet depth . . . . . $B = \frac{D}{2·08}$

and for 3·0 feet „ . . . . . $B = \frac{D}{4·08}$

So that finally, as a rough and ready rule, it is found that the values of B should never be less than half the discharge in small channels; but for large canals may be as low as one-fourth the discharge, provided in this latter case we are content with the limit of 3·0 feet full depth below full supply level.

These widths are unexpectedly large and in may cases will be impracticable. Thus there is a site on the Western Jumna Canal where one bank only is very dangerous, and the discharge being 6,000 cusecs, the width required would be $\left(\frac{6{,}000}{4}\right)=1{,}500$ feet. Here it will be necessary to be content with silting up to 4 feet below full supply level and this would still require a width of about $\left(\frac{6{,}000}{6\cdot5}\right)=920$ feet. When this limit has been reached, part of the outer silt and outer bank will have to be used to raise an outer very wide berm to the original canal bank, up to full supply level at least.

Mr. Benton thought the difficulties discussed by Mr. Kennedy do not present themselves in practice: he said that what happens is that side silt berms form, and a channel of the same area as the canal and of about the same width and depth remains to be silted up by the "In" and "Out" system: this is what had actually occurred on the Chenab Canal.

Mr. Hill said that in Bombay at any place they specially wanted to protect below a regulator or a bridge, recourse was had to bushing; the bushes were put in at intervals of one yard, and it then silted up very rapidly; in order to silt up the berms a double row of planks has never been used.

Mr. Kanthack remarked that on the Jamrao Canal spurs the bushes were packed very tightly; Punjab practice is to leave them as open as possible with a view simply to break the velocity and thus encourage the deposits of silt.

Mr. Hill replied that in that instance the canal was scouring the sides of the bank, a very different matter; the water was not above the level of berms.

Mr. Nethersole said the United Provinces practice was to set back the banks in preference to other devices for strengthening them.

Mr. Johnston referred to the Lower Ganges Canal having been made double the size required, and enquired if this had been corrected by silting up the surplus width.

Mr. Marsh said the canal was not made quite double the width necessary; the authorities cut down the scope of the scheme. The facts were, there was a great deal of the tract commanded that was originally meant to be watered, which was fairly protected by wells, when this was eliminated from the scheme a good deal of the channel was too big. When the Nadrai Aqueduct was wrecked, the first 30 miles of this channel was used largely to pass water away into the escape. Weeds grew and became a nuisance; and Mr. Beresford commenced to contract it to obtain a higher velocity; this swept away the weeds and roots. Mr. Marsh carried on that principle by putting the earthen spurs still closer; and thus got an invaluable berm along the edge.

Mr. McLeod continuing this subject said in the first instance the spurs were kept 1 furlong apart, then at half furlong intervals and lastly at 55 yards. The main ones are protected, the others merely turfed; they stood perfectly well. There is very little jungle wood available near the Lower Ganges Canal, so it could not be used as, Mr. Benton said, is the practice in the Punjab.

Mr. Marsh said he was for many years a great advocate of brushwood spurs; they answer perfectly well for half the year, then, as soon as a closure comes, they are exposed and rot.

Mr. Hill enquired from the President what width he would recommend banks to be set back; he said that on the Jamrao Canal some of the banks were set back 50 feet.

Mr. Benton thought they should be set back sufficiently far to give a good substantial bank, say, about 15 feet; in the case of a canal crossing a very deep depression 30 to 40 feet might be advisable.

Mr. Preston thought there are two considerations which come into play, (1) the amount of earth given by the grading for making banks, that is to say,

the amount the bed is below, or possibly above ground, on which depends the amount of earth required from borrows to make up the minimum banks, (2) the amount of earth required for the ultimate bank; if there is sufficient earth from the digging, then the question is merely one of setting back the banks sufficiently far to get a watertight bank ultimately. The first question determines the amount of earth required to be dug in the interior of the channel; the second is simply a question of getting the silt for a watertight bank. Punjab practice has been to endeavour to obtain a 10 feet silt berm, and he thought that is ample; if a silt deposit of 10 feet could be obtained, he thought there would not be much leakage. An excessive width of silt berm encouraged the growth of jungle and required considerable expenditure on maintenance. He therefore thought ten feet is sufficient to set the bank back if there is enough earth in the excavation to make the banks, if there is not sufficient, they should set back sufficiently to get the soil required to make the normal banks.

Mr. Benton's paper on the Syphon Proposed for Passing the Supply for Lower Bari Doab Canal Under the Ravi.

Mr. Preston said he would like to know the basis for the statement in paragraph 6 (ii) "that the steel tube syphon with ⅜" plates could not be regarded as a permanent work since the tubes would have to be renewed at great cost in about 25 or 30 years." If it is a pure guess, based on the supposed life of cast iron pipes used for conveying water for the supply of towns, he would not be prepared to endorse it. He thought the matter is important, and the circumstances would be much altered if instead of being 25 to 30 years it proved to be 50, 60 or 70 years. He regretted that he was unable to give data on this point, but he was able to indicate where it might be obtained. Twenty-two years ago he had built a syphon of this description, under the Sutlej Navigation Canal. Speaking from memory, it consisted of either ⅜" or ½" boiler plate, and was set in 18" of concrete. He had never heard of any trouble in connection with it. He thought that if the Punjab Engineers could dry this syphon and bore through one of the plates, it would give valuable experience and be worth spending a few hundred rupees in making an inspection of the condition of the plates. The drawing must be in the Executive Engineer's office showing the material used in it. If this were done, it would be possible to deduce something for guidance in future; at present we have nothing to go on in determining the life of iron in these circumstances.

Mr. Marsh said there is an iron syphon near Saharanpore which was built in 1860; it has worked satisfactorily.

Mr. C. A. White also knew of a 3½' pipe which was laid in the Panjeapara river in 1889; it was made of ⅜" iron plates, the whole being sunk below water level; the other day he enquired how it was answering and was informed that it is as good as ever; it is in salt water and has got a little silted up; it passes 25 cusecs.

Mr. Benton considered the suggestion a very important one and he undertook to carry out the examination suggested, the result is given in Appendix A below.

Mr. Kennedy said if a masonry syphon is possible at all, the design is very suitable and sound in every way. The only extra precaution he could suggest is, that the upstream side spurs should be longer and more like "Bells Bunds" with curved ends, as otherwise the river might easily get behind the ends of the syphon. The possibility of unwatering down to 27 feet or even 20 feet below spring water level seemed to him more than doubtful. The whole foundations would become more or less a quicksand and under such conditions it would be impossible to ensure a really sound concrete foundation slab—particularly as the thickness under the inverts is only 1·4 feet. Sand would be sure to blow up with subsequent settlement and cracks. It is one thing to pump down to such depths for a weir, when merely loose stone is filled in, and subsequent settlement is immaterial, but quite another thing when the foundations must be absolutely stable.

The alternative of a weir to pass the water across the river seems to deserve more consideration and may possibly turn out the best solution of the problem. The objection to the great amount of heading up required, 8′ to 16′ (paragraph 5), may be to a great extent remedied by taking the crossing 5 or 10 miles farther up the river, *i.e.*, keeping the canal levels on the left bank of the river as fixed at the present reduced level. The gain in this respect would of course depend on the difference in slope of the river and canal which is probably about one foot per mile. No undersluices should be necessary here and a simple shutter weir, 1,300 feet long, would be all that was required, costing probably much less than a syphon. A collateral advantage in a weir would be, that in case of need a supply could be sent down to the Sidhnai Canal, and sooner or later, at certain times of the year, this would be required. In fact even if a syphon be built, provision should be made for passing a supply into the river for use in the Sidhnai Canal if not merely to act as a safety escape.

Mr. Benton in reply said he had had an alternative design prepared with the whole work raised 7 feet, which would reduce pumping from 27 feet to 20 feet, but would involve lengthening of the syphon and building the work at a level which would make it a weir 3 feet in height over mean bed level of the river, while the cost would be 2½ lakhs of rupees greater than that of the design under consideration. The river basin does not offer any facilities for the alternative proposed by Mr. Kennedy which would involve heavy expenditure on training works. It is recognised that long spurs are desirable in connection with the syphon, and that heavy cost is the only objection: they will be made of sufficient length to ensure safety. As regards the supply of water to the Sidhnai Canal it must be remembered that water thrown in at the syphon crossing would be mostly lost in the drybed of the Ravi before it reached the Sidhnai Canal head works; 4,000 cusecs might be lost in the distance to be traversed.

Mr. Kennedy had said no undersluices would be required; but he (Mr. Benton) was of opinion they would be necessary, as it would be impossible to take off from any river like the Ravi without undersluices.

Mr. Marsh enquired whether if water was lost to the Sidhnai Canal it would not benefit the lands, but was informed that there is no *kadir* or low lying land on the banks of a river to the Ravi in this length. He suggested that it might increase the spring level, but Mr. Kanthack who knows the locality did not think it would. Mr. Marsh, continuing, said that recently in connection with the proposal to convey water from the Sarda River to the Ganges it had been estimated that a scheme similar to that suggested by Mr. Kennedy would be better than a syphon.

Mr. Nethersole also thought level crossings had been found advisable where they could be arranged. Mr. Rose objected on the grounds that a level crossing meant loss of water. Mr. Benton had estimated that the loss by absorption in 200 miles of the river Ravi would be 4,800 cusecs.

Mr. Preston suggested that this might be a case in which a barrage of the Madras type with gates of large span might be most suitable. He said that in his official capacity he would have to note on the work now under consideration, and he would be very glad to know the cost of a crossing on the Madras principle. He believed the bed of the Ravi is clay which would make it very suitable.

Mr. Maconchy enquired whether a lot of silt would not collect above the gates, and Mr. Benton added that it would be necessary to consider this question; it was stated at the previous days' discussion that in Madras there is not as much fine sand as in the Punjab rivers.

Mr. Davidson admitted that although the material in Madras is not so fine there is a lot of sand and the canals do silt up for the first mile or so. He thought the gates across the whole river would, to a great extent, remedy this, as when the river is in flood instead of checking it by a weir the gates would be raised to let it go past carrying the silt with it. The view he took of the advantage of these gates was as the river falls the velocity decreases and the movement of sand is very much reduced. By the time the gates are lowered the velocity has been so far checked, that the same amount of sand

cannot be carried as before. The sill on which the gates fall is absolutely on bed level thus offering no obstruction, the sill of the canal should be above river bed level, and its alignment at right angles to the river.

Mr. Benton agreed that the suggestion for a barrage, if the cost will not forbid it, is perfectly practicable and has many advantages; it would be necessary to consider (1) first cost, (2) cost of renewals, (3) cost of maintenance and establishment on the works. In reply to Mr. Baker he said it is not absolutely necessary to study economy too closely if the work is really advisable on engineering grounds, but it is very desirable to do so as engineers must consider both economy and efficiency.

Mr. Rose invited attention to the question of downstream protection It seemed to him that with a discharge of 200,000 cusecs in the river and with a berm of 50 feet wide and 3½ feet thick, the apron shown in the design is quite insufficient; the action on it will be very great, and he thought there should be considerably more protection downstream than is proposed.

Mr. Benton admitted it may be desirable; it is a question of how much is necessary under the circumstances which are rather unusual; in this case the foundations are very deep and it is scarcely likely that the work can ever fail by scour, and in any circumstances the protection can be increased afterwards if found necessary. There is no reason to suppose that the foundations will consist of a quick sand.

Mr. Preston referred to paragraph 6 (*i*) of the paper in which it is said "the cost of a tube syphon would greatly exceed that of a masonry one, the amounts of the two estimates being Rs. 22,82,867 and Rs. 19,89,870, respectively." He did not question the statement which is doubtless founded on estimate, but he was extremely surprised it is so and would like to know the reason.

Mr. Benton said that steel tubes ⅝ inch thick and 11·4 feet in diameter would require to be cased in a mass of concrete about 15 inches in thickness since a foundation for them would be required; also some protection would be necessary on the top: this casing enhances the cost. It had been estimated that if cased in clay a steel syphon would be cheaper, but he considered it very necessary to have concrete to prevent deformation and collapse of the tubes. He had considered the use of reinforced concrete for these tubes. A 6-inch layer of cement concrete would be required at the top for the steel to be embedded in, while it is uncertain if the Portland cement and kankar lime concrete will have the same rates of expansion and contraction and continue to adhere together.

Mr. Stanley suggested that a thin arch of cement concrete would be sufficient for all purposes. A thickness of 8 inches at the outside at the crown of reinforced concrete promises to answer, and he gave measurements of materials employed in the construction of a Light House.

Mr. Benton, however, considered a strong wearing protection coat is required at river bed level, and was of opinion that thin unprotected arches would be unsafe. He was, however, prepared to consider the question of reinforced concrete, but as a great deal will depend on the syphon it would be advisable to have some experiments made before implicitly relying on this device.

Mr. Mackenzie enquired if it is necessary for reinforced concrete to be made with Portland cement.

Mr. Stanley said he believed it is and that lime concrete will not answer. He heard that some experiments are being made by Mr. DuCane Smithe in the Punjab, but no conclusions have yet been arrived at.

Mr. Visvesvaraya said some experiments are also being made in Poona with local lime.

Mr. C. A. White alluded to the syphons on the Tribeni Canal for passing drainage under the canal. The question he was interested in is the thickness

recommended for the crown of the masonry arch; Mr. Buckely calculated for less than one-third of the hydrostatic head of pressure, Sir T. Higham said it must not be less than one-third. In one of these papers the thickness is stated to be 0·4 of the head. At present Bengal practice is to make it one-third. These streams are near the hills and torrents come down in flood suddenly, so he thought the shock from static pressure should be allowed for.

Mr. Benton thought what should be done is to work up from the evel of the water downstream, taking into account resistance in the syphon barrel, loss of head at the entrance and loss of head in giving increased velocity: the hydraulic gradient can then be drawn which will show the head at any point. The thickness should be such that the weight of masonry resisting blowing up action will exceed the pressure of the water unless the work is to be given tie rods or to depend on the mortar to a small safe extent. The coefficient 0·4 was only used as a first rough approximation. The theory is clearly laid down in the paper on the Ravi Syphon: the only loss of head not taken into account is that due to changes of direction which is very small in amount. He did not recommend procedure by rule of thumb: adopting the accepted theory on the subject as laid down in Professor Unwin's Hydro-Mechanics it can be seen on deducting the weight of the masonry from the upward water pressure what is the resulting bending moment and intensity of stress at the crown of the arches: if the intensity of stress on the mortar is low and quite safe, the design may be accepted as secure. He was prepared to rely to some extent on the tensile strength of the mortar if there is a factor of safety of 8 to 10.

APPENDIX A.

Wrought iron tube syphons under the Sutlej Navigation Channel, Sirhind Canal.

	Syphon at mile 41—540 feet.	Mile 45—2100 feet.
Original thickness	$\frac{1}{4}$ inch	$\frac{3}{8}$ inch.
Present "	$\frac{7}{32}$ inch (full)	$\frac{5}{16}$ inch.
Period in use	23 years	13 years.
Present condition	Covered with a thin coating of rust but otherwise in good condition.	Very slight coating of rust but in good condition.

The above seems to show that the wear of iron tubes in these circumstances is very small, and that they will probably have a long life.

Mr. Farrant's paper on Steel Tube Syphons, Swat River Canal.

Mr. Preston said the only remark he had to make was as regards what is said in paragraphs 9 and 10, a very much lower head though the syphon has been found necessary in actual practice than is given by the formula used. A fall of 4 feet had been allowed in the design; the fall through the work had never reached 3 feet even for the largest discharge that had been originally calculated for. The original maximum discharge was 94 feet, in the last observations the discharge was 102 feet with a head of 2·79 feet. Expansion joints had been provided, but he understands from the paper that they have never come into operation.

Mr. Nethersole enquired if this syphon was found cheaper than a masonry one.

Mr. Preston thought it unquestionably was; a reference to the diagram shows that there is a head of 40 feet of water on it. If a masonry syphon had been made with a 40 feet head of pressure it would have been necessary to go down very deep; indeed in these circumstances an iron structure of some kind was imperative. He thought these syphons had been eminently successful and they have worked extremely well; he had built seven at least under varying conditions; but those on the Swat River Canal are the largest.

Mr. Nethersole remarked that if Mr. Benton found an 11 feet steel tube too expensive, he might arrive at a cheaper design for the Ravi Syphon recently discussed by adopting smaller tubes requiring less expenditure in concrete casing.

Mr. Benton said this had already been worked out, and the smaller tubes have been replaced by larger ones in order to reduce the cost. Steel tube syphons are proposed to be largely used on the Upper Chenab Canal, as the discharges are not very accurately known, while works of this class will not fail by blowing up.

Mr. Mackenzie asked if the question of expansion and contraction does not apply to reinforced concrete, and whether reinforced concrete could be made with stone lime mortar.

Mr. Stanley stated that it depends on the adhesion of the cement concrete to the metal embedded in it, which is very great, and on the fact that the expansion of steel and iron is almost exactly the same as that of cement concrete.

With reference to the question of the discharge through these syphons Mr. Kanthack stated that cases had been worked out and it was found that loss at entrance and that due to bends could be ignored without causing an error of more than one per cent. Mr. Farrant's method of calculation was complicated.

Mr. Farrant's paper on the Design of the Suketar Superpassage, Upper Jhelum Canal Project.

Mr. Kennedy remarked the "humping up" of the torrent bed by 3·0 feet will no doubt ensure a free outfall, should the bed down-stream ever rise; but on the other hand, should the bed ever scour (which is just as likely as its rising) there would be a most dangerous rapid behind the right abutment, with a standing wave, and possibly a velocity of 20 or 30 feet per second. He did not think this contingency had been sufficiently provided for in the design; the rapid floor should, in his opinion, be carried 3 or 4 feet below present torrent bed, and end in a drop wall 10 feet deep; and the slope itself should be of heavy hammer dressed stone, cement pointed. It is impossible to say how these torrent beds may vary—that on the Sirhind Canal—referred to in paragraph 4 of Mr. Farrant's note, has slightly risen, due to the river receding farther from the canal. It is not stated in the paper whether the same action is possible. Scour might result from the rivers approaching the canal, or from an extraordinary flood.

Mr. Benton replying said the "humping" was given to ensure a free outfall. The Jhelum River may recede a mile or so, which would result in the bed of the torrent rising at the site of this work. It was desired to avoid the difficulty now experienced at the Siswan Superpassage on the Sirhind Canal where the bed of the torrent has risen about 3 feet owing to the Sutlej River receding. The velocities mentioned by Mr. Kennedy are greatly in excess of those possible at this Superpassage. The design is a project one and not the final working plan. The advisability of lowering the work and especially the talus of the rapid are questions which will be considered afresh in preparing the final design.

Mr. Kennedy's notes on "Absorption Losses on Canals."

Mr. Hill said Mr. Mawson had asked him to put the following point before the Conference. He said that absorption varied according to the soil, when the soil was hard the proper thing to do was to run the water as fast as possible, then he argued that where the soil was very porous it was better not to run the water fast but slowly and let it silt up the bed. Mr. Hill could not quite follow his argument of running the water slowly, the velocity should diminish the loss by absorption.

Mr. Benton said speed of water had not much to do with the matter; a high velocity would prevent the deposit of the puddle lining that the water travelling at a slower velocity might lay down.

Mr. Hill seemed to think that the faster the water flowed the less the loss would be, as it depends on two factors—

(1) Character of soil;

(2) Wetted area.

Mr. Preston said his difficulty in connection with percolation was to see it; he had tried many times but had never been able to see the water going through the soil. As an instance, on the Chenab Canal the subsoil water at Lyallpore, when canal operations began, was 108 feet below the surface, he dug a well right alongside the canal bank and carried it down to 30 feet and yet he never came to any damp soil, it was all dry; that the water does go down is obvious as he has been informed the 108 feet water level in the well has now risen to 90 feet, *i.e.*, a rise of 18 feet in ten years.

Mr. Benton said he had done the same thing as Mr. Preston and got the same results.

Mr. Rose said that on the Bari Doab Canal a great deal of water can be seen going off, but Mr. Preston observed that it is not absorption, but leakage through the bank, which is different.

TUESDAY AFTERNOON.

The papers set down for this meeting were—

17. Mr. Hill's paper on "Earthen Dams."
18. „ „ „ „ proposed High Masonry Dam-Bhandardara.
19. Mr. N. F. McLeod's paper on Injury to the Narora Weir and the Repairs.
20. „ „ „ „ Failure of the Nadrai Escape.
21. Mr. M. Visvesvaraya's paper on a new form of Module.

Mr. Hill, who presided, opened the discussion by saying—

His papers all related, to one subject, he had only a few remarks to make, he was of opinion that the back of a dam should always be made of some material that is not affected by water, also a watertight core is required. The Bombay Government asked that a few experiments might be made to ascertain the saturation of banks; in the Deccan a great many tanks have not filled in 1904, so it has been impossible to make many experiments yet. One point has, however, come out, namely, that the earth is saturated, trial pits have been dug in the bank in some cases, and in others holes have been bored and it has always been found that water rises in them.

In the case of the Hubli Water Works dam, which has been constructed lately, there is good drainage, and the line of saturation comes roughly to 3 to 1. Holes were made in the bank with a drill and water rose in the bore holes the line of saturation shown on Plate No. Volume III is the actual water level in the dam.

Another curious thing was found, namely, that when the tank was falling the level in the test hole nearest the water side was actually a little higher than the water in the tank; showing how thoroughly saturated the bank must have been.

The fact of the water falling more slowly in the bank than in the tank shows how necessary it is that the back of the tank should be of some material not affected by water.

Mr. Maconchy gave details of a dam in connection with Bradford watersupply, which bore out Mr. Hill's idea that the toe is the weak point; if it cannot be drained thoroughly by some material unaffected by water the bank will go.

Mr. Hill continuing, said, if the foundations of the dam are watertight, the water must go through the toe of the dam. The drain should be all the way up the bank by making the whole of the casing at the back of the bank of good material.

Mr. Manners-Smith said in some of the tanks at Jeypore Mr. Hill's arrangement is carried out, the rear of the slope is practically a natural filter which has not been found to silt up. The core walls are not carried down to the rock.

Mr. Visvesvaraya said on the Shetphal tank in the Deccan the slope of saturation is 2·71 to 1, the toe has answered very well.

Mr. Preston enquired whether these tank embankments have a puddle wall or not?

Mr. Hill replied that the centre part of the dam is practically puddle, being of selected material, *i.e.*, clay or black cotton soil mixed with moorum (disintegrated trap rock).

Syed Jaffer Hussin said there are two reservoirs in Gwalior State of which the bunds are made of black cotton soil but they have no puddle core, the inner slope is 2 to 1, and there is a lower plaster like pitching. He noticed when the depth of water rose beyond 15 feet, and if the hydraulic gradient was less than 5 to 1 there is invariably a bad slip at the toe. In 1904 in the Tonga reservoir there were four very bad slips and the gradient was 4·38 to 1, the height of water being only 15 feet. In 1903, in the reservoirs where the gradient was steeper he decreased it by putting in a berm of gravel, and then a course of stone ballast. This year there had been very heavy rainfall in Gwalior, *viz.*, 45″ in about 55 days.

In all the banks which were constructed water flowed out, and afterwards they slipped badly under 15′ head, with a gradient of 4·2.

In the paper under discussion a gradient of 4 to 1 has been proposed for heights up to 40′, it seems to him possible that there may be some difference in the soil or the gradient suggested may suit bunds that have a puddle core or a hearting of selected soils; but his experience is that in bunds made purely of earth there is always a breach with depths above 15′ if the gradient is less than 5 to 1.

Mr. Hill thought that the above bears out precisely what he wished to place before the meeting, namely, that unless the toe of the bank is made of some material that won't slip when water percolates through it there will be trouble.

Mr. Marsh asked what is the meaning of water coming through watertight material?

Mr. Hill replied it percolates. If you have a deep central puddle trench and the back is founded on porous material, water might not percolate below the dam; if the dam is on ground level and is founded on rock then water must appear at the toe.

Mr. Marsh enquired whether material could not be got below which will completely stop it?

Mr. Hill had known water go through a concrete wall; material will be wet even with a masonry core.

Mr. Preston said it seemed to him from the section of the Hubli Watersupply that a toe wall had been deliberately introduced which will prevent drainage.

Mr. Hill agreed and thought it probable that the toe wall is really of dry stone, carefully built. As a reference to the levels shows that the water level on both sides of the toe wall is about the same.

Mr. Davidson wished to ask a question regarding the Unkal Tank. Would there be any danger of the water getting sufficient velocity and carrying away the earth underneath the passage between the earth and the rock. In Madras it has been considered rather necessary to put in a solid core wall.

Mr. Hill did not think there is any flow through the dam sufficient to carry away the earth. In cases where a dam is founded on rock the practice is to put in a masonry wall a few feet high. He did not think it is necessary as he is of opinion the earth will make a perfectly sound connection with the rock. He was afraid of any earthen dam that reached a height of 70 to 80 feet.

Mr. Marsh stated that he knew of a tank in Agra filled with canal water. Before any remedy was applied water ran out of it just like a sieve; he obtained blue clay from the neighbourhood and put in about 2 feet at the bottom of this tank, since that time they have never lost a drop of water. When it is said that water passes through a watertight medium he supposed something of that kind could be done.

Mr. Hill did not think so, and said if he had the clay he would put it only into the essential core.

Mr. Nethersole enquired whether puddle walls would not be of use in lowering the line of saturation. It seemed to him a very important point. Puddle costs a good deal more than ordinary earth, if it is of no use why it is used at all, if it is of use why not employ it more extensively. At any rate above the line of natural saturation that would enable the thickness of dam to be reduced.

Mr. Preston thought a good deal depended on what is called puddle. The puddle he had seen used upcountry, is not American puddle, nor is it the puddle used in England. Puddle in England is an expensive material, very solid, the material is often carried very considerable distances, and it is invariably prepared in a pug mill; as far as his experience goes that is not the case with so-called puddle in this country.

The great point is then, what is the class of puddle used in practice in India? in this respect it is not he feared what was really American, Continental or English material.

Mr. Nethersole explained that a puddle-mixed with gravel can be made which will not crack. In Bundelkhand the best material obtainable is black cotton soil; what he wanted to ascertain is whether this can ever be used in the way Mr. Hill refers to or not, and whether a puddle wall would be worth using in connection with it.

Syed Jaffer Hussain said he constructed a puddle core wall 26′ high of black cotton soil, mixed with *kankar* (nodular limestone); the puddle was prepared and the wall constructed just like the walls of village houses, it was well rammed and covered with dry earth; in this way the wall was finished; the water rose up to 21′, there was a rainfall of 5 to 6 inches, the water collected in the *nala* or stream, and after a fortnight it took down the whole of the outer toe, afterwards there was another heavy shower and the whole bund was washed away. When the matter was enquired into it appeared that water percolated through the puddle wall; later on the earth was removed to expose the puddle wall, it was found cracked up over ten feet in length.

In 1902 he constructed two core walls with hollow masonry each having 8′ clear chambers; up to now they are quite safe, there is no sign of the outside earth getting moist.

Mr. Preston thought that if a puddle wall is made of good material, carefully prepared and laid as carefully as bricks and mortar it is good, but the great fear and danger is that it is not carefully laid and it is then a source of danger.

Mr. Hill in introducing his paper on a proposed high masonry dam at Bhandardara, said the proposed dam will be 250′ in height and the pressure at the bottom of a dam of that height will be rather high.

At the Pausa dam a great many experiments were made as to the crushing strength of mortar, and from these experiments it was found that with kankar and lime a crushing strength of over 1,500lbs. per square inch can be ensured. He thought it would be quite safe to increase the pressures higher than has been the practice in the past and for the dam design at Bhandardara 210 lbs. per square inch might be assumed. He asked if any gentleman had made any experiments in connection with the crushing strength of materials? He did not think the factor of safety, 5 or 6, is too small. Another difficulty in high dams is the outlet sluices when working under a great head, as the friction is very great. Stoney's gates have been suggested, he feared the use of gates which may stick if there is no possibility of pushing them down; perhaps there might be an 80′ head to work against. In the Bhandardara dam it might be as much as 150′. It did not therefore seem safe to rely on the gate being lowered by its own weight. Mr. Beale, Superintending Engineer in Bombay, has designed a number of dams and suggests that a dam instead of having a regular profile should be built in steps, one advantage he claims is that it facilitates scaffolding in building; he thinks that for great pressures it is possible to use different material, also that in calculating the pressure on the downstream edge of a dam it is not safe to calculate for a horizontal joint; it should be taken as planes inclined towards the water face and for inclined planes the pressure is greater.

Mr. Mackenzie objected to building a dam in steps, he did not object to building the water face in steps; but it is unadvisable to build the downstream face that way, it requires much looking after as jungle seeds lodge on the ledges and germinate: he knew a dam built in steps which was eventually filled up with concrete because of the difficulty of keeping it clear. He strongly urged the advisability of making the downstream side smooth.

Injury to the Narora Weir.

Mr. McLeod thought there were a few things to notice in addition to what he had said in the paper.

The first structure of this type, the only other river weir then completed in the provinces, *viz.*, that across the Jamna below Delhi, being merely a heavily revetted stone bank thrown across the river and resting on the river bed. The designers of the Narora weir wished to carry the foundation wells much deeper, those on the downstream side into the clay substratum, and on the upstream 15 feet below floor. This was overruled by the sanctioning authority so that the crest wall wells are only 7 feet below floor and the downstream wells 17 feet below floor. The intervals between the crest wells are very thoroughly closed with piles and concrete, and those between the lower wells which are cylindrical are but imperfectly closed with piles.

While the work was under construction, the floods were passed over a part of the completed floor and the under-sluices, there was strong scour along the face of the weir crest which was shaken and slightly subsided and the floor cracked to a length of 256 feet. This accident showed the necessity for protecting the upstream face and the kunkur and puddle apron was then introduced and the scour along the face wall restricted by pitched cross spurs. These were too weak in section, they were some 80 feet long, with a width of 5 feet, and were carried up to about 3 feet below crest level. They were invariably carried away and finally were replaced by two strong groynes, one on the left flank of the under-sluices, the second in the centre of the weir. These groynes are about 610 feet in length over all with a top width of 48 feet and 1 to 1 stone pitched side slopes 5 feet in thickness. Downstream of the weir it was originally intended to carry the talus down to the clay bed, it being considered that the scour would gradually carry the material down to the lowest level. There has practically been no scour except towards the under-sluices.

When the failure occurred a strong spring burst up at the toe of the crest wall and passing under the floor below the ashlar blew a length of 200 feet of it upwards, it was raised to a maximum of 2 feet but not a single stone was blown clean out. Then the pressure passed under the floor through the lower curtains and blew up the grouted pitching below.

The remedies applied are as shown in the plans. Upstream a strong protective apron consisting of 2½ feet clay puddle covered with 2 feet of pitching which is divided into compartments by cross-walls of block kunkur set in lime at a distance of 70 feet from the crest wall, a line of closely driven sheet piling encloses the work. Below the crest wall the injured floor was thoroughly repaired. A crest wall 3 feet above floor was built along the downstream edge of the floor to keep pressure on it. Such a cistern formed part of the original design but had been omitted during construction.

The pressure experiment instituted by Mr. Beresford has been continued. Previous to the failure there is only one observation with which comparison can be made. Recent observations show that there was no decided lessening of pressure immediately after the construction of the protective apron and pitching but there has been a gradual reduction since.

In reply to Mr. Hill he said it is 25 feet from the stand pipes to the free sand below the curtain walls, and that for a heavy pressure of 5 feet he would like a length of 45′, below the pipe. Mr. Hill thought that this seemed rather short, he was under the impression that for loose sand it was hardly safe to have less width than ten times the head.

Mr. Nethersole thought Colonel Clibborn who made lengthy experiments with Ganges sand recommended a minimum of 1 in 12.

Regarding his paper on the failure of a fall on Nadrai Escape.

Mr. McLeod said there is a 14′ drop; the work was placed in rather an unfortunate position, being parallel with the main canal at a place where it is very high so that from the beginning there was a good deal of trouble from springs. In the two years previous to the actual failure they had been obliged to run the canal very steadily owing to the necessity for sending large volumes down to supply the Lower Ganges Canal during the construction of the Nadrai Aqueduct; the escape also had been run continuously.

The first sign of failure was shown by the crack along the downstream walls. That has always been the first sign of failure in these works, either upstream or downstream, it just lifted the floor, that was repaired by an extension of the floor.

Next year the same thing happened again. One morning the whole work collapsed, a great hole was blown in, and the whole of the crest wall sank, leaving the rest of the work intact. There was nothing to be done.

There were some similar falls built last year and they all gave trouble.

Now that type of fall has been given up and two falls of 7′ are constructed instead of one of 14′.

Mr. Preston said Mr. McLeod seems to imply that the fall had failed because there was a 14′ drop, but one or two of this height had been built in the Punjab and had given no trouble. This was confirmed by Mr. Benton.

Mr. McLeod added there was a very short length of floor, and a 20′ of head of pressure with very little upstream protection, this gave a great intensity of pressure on a weak point, added to which there was no protection downstream.

Mr. Marsh said he had looked through the notes on the construction of the work and found that Colonel Brownlow had recorded that he knew the fall would not stand, but the Government of India declined to give the money required to remedy the defects. There is a fall of 27′ in the Bulandshahr Division, which has not given any trouble.

Mr. Visvesvaraya's paper on a New Selfacting Module.

Mr. Hill said the following is a short description of the module which Mr. Visvesvaraya has given me. The drawing shows a module intended for a discharge of 5 cusecs. The section at the lower left hand end gives a clear idea of how it is to be worked.

The module is intended for the present chiefly for the irrigation of crops like sugarcane for which there is a steady demand throughout the year.

Even if the saving of water is 10 to 15 per cent. only, the extra revenue by the extension of cultivation will be Rs. 150 to Rs. 200 per annum.

The cost of the module per cusec is estimated at Rs. 200 to Rs. 300, and will pay for itself in 2 or 3 years.

By the use of floats of wood, much cheaper modules can be made on the same principle.

It is not proposed to sell water by volume. Once in 6 or 8 weeks, the crops under an outlet will be watered by a trained canal staff and the discharge and time observed. From the results of this watering, the discharge and period of rotation will be fixed for all intermediate waterings.

The accuracy of the module can be tested by observing the time taken in emptying the chamber previously filled by a given depth, after closing the inlet.

(The reporter found it difficult to record the discussion as there was a great deal of cross-conversation.)

Mr. Benton pointed out that by this arrangement the loss of head would be 2′ this was a great deal more than could be allowed on the Punjab irrigation works; it might however do for supplies from tanks. He did not understand what was to prevent the lower part being filled up with silt.

Mr. Visvesvaraya explained that the design is intended for the Deccan which is a rolling country and that in the Deccan there is not much silt in the water.

Mr. Kennedy stated several objections to the design and added that a similar one had been already tried and had failed.

THURSDAY MORNING.

The papers set down for consideration were :—

22. Mr. Reid's paper on Lift Irrigation.

23. Mr. Gebbie's paper on the System of Irrigation from the Jamrao Canal.

24. Mr. Morin's paper on River Training in Tanjore.

25. Mr. Maconchy's paper on "Flood Drainage."

26. Mr. Marsh's paper on Increase of Torrent Floods in the Upper Reaches of the Eastern Jumna Canal.

Mr. Reid's paper on Lift Irrigation.

Mr. Davidson, who presided, said :—This paper is, I think, rather what might be described as too "previous", it talks of pumping by a series of wells in a continuous connected line with electric power as the motive power.

His own view was that the subsoil water supply is problematical; he would like to hear the views of those present as to what could probably be done with subsoil water and what effect it would have if the question of pumping indiscriminately all over the place was seriously adopted.

In Madras wells irrigate 3 or 4 acres by means of bullocks and a picottah; the wells are far apart; if all the wells contemplated in the paper were put down, they would injure each other, the same source of supply would be drawn on by everybody.

The question of pumping had been considered in Madras to a certain extent. An Engineer was appointed to work out figures and it was found that unless 30 to 50 acres be irrigated, it would not pay expenses. It must be remembered also that the well will be emptied by pumping of as much water in two hours as the ryot lifts in 8 hours, and it will then be necessary to wait for it to fill again. Mr. Reid seemed to think there is an inexhaustible supply; his paper makes a reference to the Divi Pumping Project; in that case it is proposed to pump from an inexhaustible supply, *viz.*, the Kistna River. Divi Island is unprotected and cut off from the Delta canals; an aqueduct was proposed, but the cost was prohibitive; recently it has been proposed to erect a pumping installation to irrigate the island. He thought it is rather a pity Mr. Reid did not lay the Divi Pumping Project before the meeting; it is perfectly sound and, he believed, would pay 8 or 9 per cent. easily. The scheme has been very well worked out by Mr. Reid.

Mr. Hill could confirm the statement made by Mr. Davidson that the supply of water from wells is very limited, some wells in Bombay dry up altogether, and the difficulty in that Presidency is the want of water. He can also confirm the statement that an ordinary well is not big enough to supply water for a steam pump.

If it were possible for the steam engine to do just the same amount of work as the bullocks, perhaps it might pay, but he doubted it; moreover, the bullocks are useful for other purposes.

Some time ago the Bombay Government put on a man specially to find out the cost of lifting water by bullocks; it had been said that there was a great waste of time in the bullocks walking back again up the ramp of the well; the actual experiments showed that during that period the bullocks were getting rest. They walked slowly and put all their power into pulling the bucket out. Another point is that the cost of wells is not calculated; no allowance is made on this point in estimating the profits of the scheme.

Mr. Davidson said that Mr. Chatterton has to some extent worked out this point. The bullock, however, pays for his keep in a way that the engine does not; but Mr. Chatterton merely compared the relative cost and lost sight of the fact that a great deal of what is provided by the ryot for his bullocks is found from the 3 or 4 acres he cultivates. It was only fair to Mr. Reid, who had left Simla owing to indisposition, that he should read the following extract from a letter he wrote before leaving :—

"Of course it is the case that the scheme is built up on a slender foundation of fact, but my contention is that till such a superstructure is shown to be possible there is no likelihood of any money being given to ascertain the facts."

He did not think Mr. Reid was right. In Madras experiments are being made to see if pumping will pay.

Mr. Benton said Mr. Reid had not taken into account in his paper the case of the wells that are not provided with power; if a drop in the spring levels occurs in them due to the machine pumping, the owners would require compensation. Mr. Reid assumes that the supply of crude oil for working oil engines is inexhaustible; that is not the case.

Mr. Kanthack commented on the coefficients taken by Mr. Reid *viz.*, that 1 H. P. at the generator will give ·33 H. P. at top of each well; he doubted if so much would be got.

The following figures are generally taken:—

Turbine	70 per cent.
Generator	90 „
Step up transformer	95 „
Transmission line	80 „
Step down transformer	95 „
Motor	90 „
Pump	60 „

This would give a total loss of power of 75·44 per cent. and a coefficient of ·2456.

Every well will require 1·36 H. P. available at the generator.

Hence only 16,900 wells can be supplied. This would make a difference in his financial results.

Mr. Nethersole said that Mr. Crampton's report on the electrical traction scheme in Kashmir made out that 50 per cent. of the power generated by the motors would be obtained for work. Mr. Kanthack's 24 per cent. therefore seemed low.

Mr. Kanthack said he had taken only 80 per cent. on the transmission line, as Mr. Reid in his paper contemplates transmission to a distance of 300 miles.

Mr. Davidson said he believed Mr. Reid's figures were the result of correspondence with Mr. Gibbs, in charge of the Mysore installation.

Mr. O. A. White said in Bengal, where the sugarcane industry has started in place of the indigo, Government was anxious to know if it would pay to pump and a few experiments have been made this year. He put in the following notes on the subject:—

"*Irrigation of Sugarcane by Pumping.—Behar, 1904.*"

"The cultivation of sugarcane in Behar has developed largely during the last few years. Improved kinds of cane have been imported and much attention given to manuring, irrigation, and tilling of the soil; it has already been shown that the output of sugar from the ordinary cane is increased by irrigation, and that imported large cane cannot with advantage be grown without it. Only a small portion of Behar is commanded by canals, consequently irrigation by pumping has to be resorted to.

"The Government of Bengal is anxious to assist the planting community by conducting experiments in order to ascertain the best method of growing sugar cane successfully, and as regards the cost of irrigation, and with this object conducted experiments by pumping from the Bur Gandak river at Otter, with a 10″ Invincible Centrifugal Pump and a 10 H. P. engine. Unfortunately a start was made late in the season, and heavy rain in May stopped the demand for water. The experiment will be continued next season with a larger plant, *viz.*, a 15″ centrifugal pump and a 16 H. P. engine.

"The information obtained from these experiments are:—That a 10″ pump with a lift of 27 feet and lead of 4,000 feet, running at 650 revolutions a

minute, can throw $3\frac{1}{2}$ to 4 cubic feet of water per second, *i.e.*, 1,300 to 1,500 gallons a minute, and irrigate at the rate of $\frac{1}{3}$ acre per hour. About 5″ to 7″ average depth of water was utilized on the fields which were trenched, 3″ to 5″ was lost in the new channels. The engine used 2 maunds of coal per hour at 7 annas a maund; labour for working the engine was somewhat excessive, costing Rs. 1-10-0 per day of 11 hours; the total cost of coal, oil, labour, etc., came to Rs. 3-6-0 per acre for one watering.

"Irrigation was carried on at several concerns by steam pumping on their own account, and the proprietors have kindly allowed the results to be published, for general information.

"It would possibly pay planters to use Hornsby's (Grantham) oil engine or some equally good one, instead of a steam engine.

"One interesting question to decide is, the number of waterings that may with advantage be given to sugarcane; in Egypt the crop is watered once every 10 days for 75 days, or an average of $7\frac{1}{2}$ watering."

Statement showing particulars of sugarcane irrigation by pumping at various Factories in the Gandak Circle during the year 1904.

Concern.	Size and kind of pump.	H. P. of engine.	Date.	Number of hours of pumping.	Rain fall in inches.	Area irrigated acres. Detail of irrigation. 1st	2nd	3rd	4th	Cost of coal, oil etc.	Cost of engine driver and labour.	Lift (height to which water was lifted)	Lead (average distance of fields from pump)	Total cost of channels etc.	Cost of irrigation per acre, single watering, column $\frac{11+12}{10}$	Remarks.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
						Acre.	Acre.	Acre.	Acre.	Rs. A. P.	Rs. A. P.	Ft.	Ft.	Rs. A. P.	Rs. A. P.	
Government figures at Otter.	10" Gwynne's Invincible Centrifugal Pump.	10 H. P.	25th April 1904 to 7th May 1904.	144	1·50	46·00	...	...	16·00	131 0 0	21 0 0	26·53	4000	*250 0 0	3 0 0	There was considerable loss due to percolation in the new channel. *Average cost of earthwork per mile.
Seeraha.	Feed Pump	"	10th March 1904 to 20th April 1904.	No record.	Not shown	80·30	16·75	...	99·05	310 0 6	10 10 0	25	1035	116 6 9	3 6 4	
"	Centrifugal Pump	12 H. P.	12th March 1904 to 12th April 1904.	No record.	Do.	148·55	35·55	...	182·10	468 7 9	70 15 9	10	3579	20 2 6	2 15 4	
"	Worthington Pump	Not known.	12th April 1904 to 5th May 1904.	No record.	Do.	76·53	4·00	...	80·53	319 11 4	52 9 6	25	4032	59 8 0	4 10 0	
"	Not known	Do.	2nd to 20th April 1904	No record.	Do.	79·15	...	...	79·15	748 8 9	50 14 9	10½	1000	50 9 0	10 2 0	
Total	......	...	......	...	...	384·53	56·33	...	440·83	1846 12 4	215 2 0	×	×	213 10 3	4 10 9	
Dundpur.	7" Centrifugal Pump	10 H. P.	......	...	No record	75	...	...	75	124 4 0	63 4 0	16	Within radius of 500 yds.	...	2 9 0	The water from the pump having been available only spasmodically, that is to say, when the pump was not being used in connection with crushing cane, has caused the average cost to be so high.
Moosheri.	Centrifugal Pump 9" and 7".	12 and 10 H. P.	......	...	Do.	60	...	...	60	145 0 0	50 0 0	15 to 20	½ to 1 mile	90 0 0	3 4 0	
Total	......	...	......	...	...	135	...	...	135	269 4 0	118 4 0	×	×	90 0 0	2 14 0	
Barhoga.	4" Special Steam Pump.	80 H. P.	14th February 1904 to 10th June 1904.	414	3·93	31·00	9·63	8·87	52·00	94 13 0	19 5 0	11	¼ mile	32 4 3	2 3 0	
"	6" Gwynne's Centrifugal Pump.	8 H. P.	2nd March 1904 to 7th June 1904.	342	3·93	62·30	15·31	5·92	83·53	89 12 0	35 7 9	21	¼ mile	25 0 0	1 11 9	
"	8" Gwynne's Centrifugal Pump.	12 H. P.	16th February 1904 to 13th June 1904.	477	3·93	102·55	36·48	10·37	149·40	233 10 0	57 12 9	31	½ mile	†377 5 0	1 15 3	† Includes constructing masonry drain, carrying water under ground 240 ft. and distributary channel.
Total	......	...	......	1233	3·93	196·85	61·42	24·66	284·93	418 3 0	112 9 6	×	×	134 9 3	1 13 10	
Otter.	6" and 8" Centrifugal 8" Special Pump.	12 H. P.	3rd March 1904 to 28th May 1904	212	Nil.	212·25	26·25	...	238·50	690 3 3	256 7 7	26	½ mile	69 2 0	3 15 6	
Total	......	...	......	212	...	212·25	26·25	...	238·50	690 3 3	256 7 7	26	½ mile	69 2 0	3 15 6	
Ramcola.	6" Centrifugal Pump	10 H. P.	20 days in March and May 1904.	...	2·6	40·00	3·00	...	43·00	100 0 0	40 0 0	28	½ mile	5 0 0	3 4 0	
Total	......	...	......	...	...	40·00	3·00	...	43·00	100 0 0	40 0 0	28	½ mile	5 0 0	3 4 0	

Dated the 22nd August 1904.

C. A. WHITE,

Superintending Engineer, Gandak Circle.

Syed Jaffer Hussain said he thought the United Provinces is the only place in which electrical power for pumping water from wells can be produced because the water which passes over the canal falls can be utilized. He suggested that a proper estimate be made with a view to introducing the system as the water power can be given cheap.

Mr. Preston said Punjab Engineers have not been unmindful of the vast power on the canals, but they have such enormous tracts still to be brought under cultivation and colonisation by new canals which will bring a thousand times more direct and indirect benefits to the State that he thought they had quite rightly devoted their attention to the construction of those canals instead of to electrical projects which can at best add only a limited number of acres to the cultivation. Until they have brought all the water possible by direct flow on to the land, he thought it would be a waste of time to go in for pumping schemes.

He admitted it is rather difficult to satisfy the lay mind on this point and he constantly heard people talking of the indifference of Canal Engineers to the waste of power, but while establishments were limited he was certain they can be best used in constructing new canals.

Mr. Gebbie's paper on the System of Irrigation from the Jamrao Canal.

Mr. Gebbie in introducing his papers on the Jamrao Canal said that in regard to the grading of the canal it has been remarked in a previous discussion that the proper thing would have been to put in another fall instead of trying to hold the bed by groynes. As a matter of fact he had made the suggestion but his Superintending Engineer did not receive the proposal with favour; Mr. Gebbie thought it would have to be done at some future date. He, however, pointed out that the groynes are *kacha* and cost only Rs. 3,000 to put in, while another set of falls would cost Rs. 80,000. There is also the difficulty that the canal would have to be closed for six months during construction as it would be impossible to make a diversion. He did not doubt that difficulty could be overcome but perhaps it might add one lakh to the cost of the fall.

The distribution of water is modelled on that of the Chenab canal system in the Punjab; the same principle has been followed, but the details differ. He would be very glad if some of the Punjab Engineers would advise them in the matter of the distribution from watercourses to each field which is giving trouble.

Mr. Kanthack said that rapids do not seem to be used in Sind. In the Punjab rapids have been found most useful in regrading the bed of a canal as they do not require very deep foundations, and can be very quickly put in; he did not think there should be any necessity for a six months' closure.

Mr. Hill said exception had been taken that in a comparatively modern canal, so steep a bed slope as 1 in 5,000 was employed. That slope was put in by advice of Colonel Ottley as an experiment. In the first grading sent in two falls were provided and the slope was 8 inches in the mile; it had been made 12 inches in 5,000 which, he says, by Mr. Kennedy's diagram would be likely to scour, and this is exactly what has happened; a proper slope according to Kennedy's diagrams would have been 1 in 6,666.

Mr. Rose pointed out that Mr. Gebbie had said the Jamrao distribution was based on the Chenab system, but it seemed to him there is no similitude at all; on the Jamrao the squares were divided into 16 acres blocks, there did not appear to be any sub-division; on the Chenab system the holding of about 28 acres is divided into one acre fields and the water is carried in a properly graded channel to each field.

Mr. Gebbie said this had been commenced on the Jamrao but had been dropped by the Colonisation Officer; there are marks on the sides of the holding to facilitate measurement, but this matter is one for the Revenue Officers, the Irrigation Department having nothing to do with it, or with the measuring of crops.

The fields are more or less actually divided off, a ridge is thrown up on the boundary but they are not divided into acre plots in every case. Where a

man has cultivated less than his holding of 16 acres he divides off what he has cultivated by a ridge.

Mr. Robertson, who was Colonisation Officer of the Jamrao system, and happened to be present, was invited to speak and explained that the division into acre fields was not introduced universally because in certain localities there were fields that had been in existence for many years and the ownership was interlaced, a large part of it was garden land and the introduction of the system would have been a very troublesome matter and have led to great opposition; it would have been very difficult to make the people give up land which they had improved, the system was carried out where irrigation had not been so constant and where improvements had not been made. The Revenue system in Sind is quite different to that in the Punjab.

Mr. Preston said one or two points only struck him. It seemed to him with reference to what is said in the paragraph in the middle of page 2 of the paper on the Head Works regarding the use of steel beams to close the canal, the interests are so large that it seemed to him it would be worth the while of the Sind authorities to provide a proper gate and suitable lifting gear instead of the steel beams. Again with reference to the last paragraph, he would like to ask Mr. Gebbie why the steel wire rope tramway has been a failure, it is a success on the Chenab, Jhelum and Sirhind canals.

Mr. Gebbie said no use has been found for it, as it is possible to get across the river in a boat even in flood.

Continuing, Mr. Preston said—Turning to the paper on distribution, to a certain extent the Sind authorities have bettered Punjab practice; in the case of the Sidhnai, Lower Sohag and Para, Chenab and Jhelum canals, the squares are made 1100 feet side. This unit had been fixed by Colonel Wace, who was Settlement Commissioner many years ago, because it worked into the native measure. Later on in surveying for the Lower Bari Doab canal, the squares were made 1045 feet side which is an area of almost exactly 25 acres; this block, when divided by 5 lines transversely and by 5 lines longitudinally, gives 25 acre fields. As regards the use of the native measure, he personally is much opposed to it, and the Honourable Sir A. T. Arundel had stated that 30 years ago in Madras they issued an executive order that the acre should be the unit and since then the acre has been the unit; you cannot go into a single district in Madras and find the native measure in existence. The difficulties in using the native measures can best be realized by reference to the Punjab Irrigation Branch Handbook of Circulars. The first thing the Canal Officer, when posted to a Punjab District, has to do is to read the circular on land measurement. He will find the units either the "karam" of 2 paces or the "gatha." The latter is 8·25 feet but the "karam" measures 4·76314 feet; 4·5 feet; 4·6 feet; 4·625 feet; 5·0 feet or 5·5 feet according to the district. Could anything be more confusing? It is, however, increased by the use of native terms such as *biswansis, biswahs* and *begahs* in the begah measurement and *sarsahis* or *square kan, merlas, kanals* and *ghumaos* in the ghumao measurement.

The Revenue Officers consider it necessary to continue this system for land measurements and this is the reason it was introduced in the Canal Colonisation Schemes. The Sind authorities have gone in for 840 feet side, which gives levels at 420′ intervals instead of at 550′ as in the Punjab. It is stated that the standard size of village is 2,000 acres, that is very big, the unit on the Chenab canal was 50 squares equal to about 1,350 acres, and there are very many villages smaller than that. Further on in the paper it is stated that the great disadvantage of these villages was the huge size of the watercourses. This is referred to in the second paragraph on page 2, it seemed to Mr. Preston to be a great defect.

It is said that the cultivators frequently bund the watercourses and thus upset the fixed rotation. Mr. Preston submitted that this is an accusation against the Canal Engineer. There must be something very wrong if a perfect system of watercourses cannot be designed. The cultivators should not be able to make better watercourses than the Engineers can.

Mr. Gebbie said they are not better, but the cultivators think they are. It, however, seemed to Mr. Preston that a properly designed system ought to demonstrate its advantages by itself; it ought not to be open to doubt.

Mr. Gebbie said perhaps a man has one block on one watercourse and another on another, instead of watering from different watercourses he wants to water both from one channel and he often turns his water from flow to lift.

Mr. Benton said Mr. Robertson seemed to think the introduction of the small square system would lead to interests being disturbed. There are many cases in the Punjab where village waste land is now being broken for irrigation, squares have been laid down in them and the people are compelled to adopt them, the argument used to induce them to do so is simply that if they don't they won't get water.

Mr. Robertson replied that in Sind they always have had water, but Mr. Benton thought the more assured supply they now get could be used as an argument.

Mr. Hill would like to thank the Chenab Officers for the help they gave the Jamrao officers in designing watercourses. He would like to know the minimum size for tail watercourses. In the last hundred acres what would be the discharge? Would it be half a cubic foot per second.

Mr. Preston said this is easily answered, the invariable practice is, wherever it is possible, to end a Government channel in a cluster of village watercourses, so that a good volume of water reaches the tail; a village watercourse is seldom less than 2 or greater than 3 cusecs.

Mr. Marsh understood Mr. Gebbie to say there was considerable trouble in the distribution of water in the watercourses, and he had not heard this answered. He understood that the people have rows amongst themselves.

The ownership in the watercourses had been broken down by a test case as to the right in watercourses and also in outlets, the Munsiff and the District Judge decided in favour of the Canal Authorities and on appeal to the High Court the decision was upheld.

He would like to say a word about minor distributaries as it is a hobby of his; he did not think any watercourse running more than 1 cusec should be left in charge of the people; those small channels have been developed immensely with great profit to the canal. In Bulandshahr there was at one time an officer, who had a great belief in large channels being managed by the cultivators themselves and he made several over to them. After three or four years Mr. Marsh found that the water only reached the first four or five furlongs and that villages further on were utterly starved; all these have been taken back and many original zamindari watercourses have also been taken over as Government channels with great advantage. If more establishment is required to maintain them he would give it as he thought it would be possible to economise the supply by perhaps as much as 20 to 40 per cent. by a proper system of minors.

On the Eastern Jumna Canal there used to be a great deal of trouble because a number of people thought they had rights in the water and they claimed the ownership of the water course and other irrigators had to pay them a royalty for water; this has been broken down, as also the periodical closure of outlets on the distributaries.

Mr. Gebbie said the Sindi is not accustomed to the Punjab system of a share list and would not adhere to it.

Mr. Preston thought the Sindi should be educated to do so.

Mr. Benton said—Mr. Marsh has not stated what would be the cost to Government of taking up the village channels; the mere establishment, *i.e.*, the number of sub-overseers is a small matter compared with the amount of Government money that would be spent in doing work that cultivators should do themselves.

Mr. Marsh said that is a very old theory. He had discussed this question with Mr. Kennedy and he settled the question by saying "the fact is your irrigation in the United Provinces has reached a very advanced stage, it consists of garden land, we have a great deal of land entirely waste".

Mr. McLeod was in favour of having as many watercourses as possible made by Government, the quicker the water gets on the fields the more economical it is ; and the minor distributaries help this immensely.

Mr. Morin's paper on river training in Tanjore.

Mr. Davidson said the Tanjore Delta irrigation system, of which a sketch is given with the paper, is peculiar in that it is absolutely natural, except for the distributaries there is not an artificial canal in the whole Delta.

The result is, as Mr. Morin explains in one of the paragraphs, there is a good deal of conservancy and upkeep. In the Godavari and Kistna Delta systems which are artificial, there is nothing like the same extent of protective works. There is no stone in the Delta, and therefore it has been necessary to fall back on Cocoanut and Palmyrah trees or bamboos and brushwood for the protection of revetment or groynes. I think as far as the Tanjore conservancy is concerned Mr. Morin has given us a very good paper. The lines on the hydrographic map are all streams the supply to which is distributed by Government. The Engineers are not concerned with the distribution in the channel itself.

He did not think there would be any benefit if they did until Madras has an Irrigation Act, at present without an Irrigation Act the vested interests overpower the authorities. The Engineers have nothing to do with the distribution, they keep up the works only ; *i.e.*, they stick to the engineering and leave everything else to the Revenue Department ; if they did the distribution work as in Upper India a large increase of establishment would be necessary and he doubted if anybody would sanction it ? Madras Engineers did not hanker for the work very much and were content to leave the distribution to the Revenue Department.

In answer to a remark that the Engineers could not know where the water goes or what was done with it ; he said they pass it through our head sluices of the main distributary. The actual distribution is not in their hands, the Revenue Officials report where they would like the water and the Engineer sends it there and has no further responsibility as to the distribution, it is the business of the Revenue Officials to see that the water reaches the tails of the distributaries.

The soil is fairly good firm alluvium, there is no black cotton soil ; I may mention that our protective works are merely to prevent scour and to keep up the margins of the natural streams.

Mr. Maconchy's paper on Flood Drainage.

Mr. Maconchy in introducing his paper on "Flood drainage" said he would like to give a brief explanation of it. A few years ago when he took charge of the Northern Drainage and Embankment Division, he was called on to design, or report on, a good many schemes for flood drainage. The circumstances, specially when the outfall was into tidal water, were very unfavourable and at first sight it seemed, in some cases, that effective drainage could only be provided at a prohibitive cost, if at all. To determine whether this was so necessitated rather "close" calculations, as in some cases the "head" available was very limited and the "lead" of the drainage channel very long. At first he was rather at a loss and could find nothing in any books available to him which quite met the circumstances. It was possible of course to work on precedent and allow say 5 square feet of ventage per square mile of drainage area ; but this was not sufficiently accurate as the *data* regarding general level of country and level of outfall varied somewhat. There was therefore nothing for it but to work out his own formula. This was not done all at once, but by degrees as the occasion arose. Some of these results have been given in this paper. He would have preferred to take an actual example of a big drainage scheme and describe it but it would have taken up too much time. His results were given in greater detail in a course of lectures he lately gave at the Sibpur College and all that was possible in this paper was to condense those lectures, or rather a part of them, much as they stood. The results have been given in the form which were found most useful in actual designing though they could be put into other shapes which might-

appear simpler from a theoretical point of view. He has worked out tables covering, he thought, every possible case, from which the results can be obtained with no more calculation than the use of proportional parts.

In Bengal these schemes, under the drainage acts in force, have to be carried out at the expense of the persons benefitted, and if the cost is too high the people won't agree to carry them out, and so it is no use trying to be on the safe side by providing excessive ventage, the works have to be designed as economically as possible. He instanced two schemes which are being, or will be, carried out both of which necessitate very "close" calculation, *viz.*, the drainage of the Argowal Circuit and the Magra Hat drainage scheme in the 24-Parganas, south of Calcutta.

He proceeded to briefly explain the contents of the paper. Paragraph 2 contains a statement of the standard formula of discharge through sluices and weirs. At the end of it an empirical formula has been given which, so far as he knew is new, this serves as a general formula, embracing all the standard ones. It is mainly useful in calculating the "time of discharge" which is dealt with in paragraph 3. These "times of discharge" do not as a rule enter into the calculations of any of the drainage schemes he has met with.

The results he had found most useful, are those explained in paragraphs 4 and 7 which deal with cases of discharge into tidal waters. Paragraph 4 gives the theoretical results expressing the value of the true mean discharge throughout the rise (or fall) of the tide. In paragraph 7 these results are made use of, and formulæ are given on which the complete design is based. Allusion has been made to the complication caused by a breast wall in front of the vents of a sluice, and in the Sibpur lectures the solution, was worked out but there was not space to give it in this paper. The practical result is that, provided sufficient waterway is allowed through the vents, it will be near enough to ignore their existence.

In paragraph 6 a table is given which will save a lot of trouble in dealing with velocity of approach. This velocity is a very important factor in the calculations for a breast wall in front of a sluice, but as a rule makes very little difference to the discharge from a channel over a weir or through a sluice.

In paragraph 8 will be found the solution of a case which seems of very great importance, *viz.*, the discharge of an open channel of which the surface is not parallel to its bed. This case is constantly arising in drainage schemes and Mr. Maconchy has not been able to find any solution of it in any book. The usual way is to work with the average surface slope; the actual surface is of course a curve and not a straight line. The above method even it were accurate, which it is not, would not however get over the difficulty "what cross sectional area of waterway is to be taken." If a channel is, say, 10 feet deep at one end and 5 feet at the other, the area is all important. He must apologise for the complicated form in which the result works out; but he fears it is unavoidable, he has calculated tables to save labour, one is given, it is fairly long but the other is much longer, and there has not been time to get it printed.

There is another method of calculation which arises in inland drainage schemes discharging into rivers or drainage channels, which can best be explained by actual examples. These are given in the lectures, but time was not available to allow of his reproducing them here.

He would be very grateful if any one would point out any mistakes or misconceptions in the results.

Mr. Kennedy said the results arrived at and specially the different tables showing the ratio between the mean discharge and the maximum as the tides stand at different stages should be very useful for the peculiar conditions, considered in this paper, and save an immense deal of time and trouble to others.

The only new point he would like to refer to is whether the ordinary formula for a partly drowned weir is reliable, see fig. 5, page 4. Theoretically of course it is all right but for two reasons he doubted if it is so practically. Thus it has been observed over and over again, that for a clear fall the coefficient is fairly constant, and about what might be expected 0·62 or 0·65,

but if the same weir becomes drowned, the coefficient at once rises, often up to 0·80 or more. Again, if means are provided at the ends of the weir, by which air can be admitted just under the sill, it has been noticed that often there is a continuous hollow space just under the entire length of the down stream edge of sill; where air accumulates and stays; and can be actually seen through clear water. The pressure at that point ought of course theoretically to be (D-h) fig. 5, but it is really D; and therefore the velocity there will be higher than given by theory. The reason of this may be connected with the action of the clear fall or upper part of the falling water, which presses down on what would otherwise be the horizantal flow of the lower or drowned part; this action not being taken into account at all in the theory. This is a question which might be taken up by some one; as there is no doubt an improved formula is wanted for discharge over drowned weirs, and drowned rapids.

Mr. Maconchy said he had avoided the question of coefficients, in his paper, as he thought it is a subject for discussion by itself.

Mr. Hill asked if he had made any experiments to find out what is the coefficient for a big gate or weir much larger than the small notches used in experiments in Europe?

Mr. Maconchy replied that he made some experiments on some outlets 15 ″ × 18″ which gave very high coefficients; he thought it depends on the nature of the approaches up to the sluices. If the bed of the sill is level with the bed of the channel it may be 0·90; if the wing walls converge properly and the bed is level, a high coefficient should be got in a small outlet 12 ″ × 18″ where the bed of the outlet was level with the bed of the canal he got coefficients up to 0·82.

Mr. Benton said he had made a number of experiments on distributaries carrying from 30 to 200 cusecs, and with heads varied from ½′ to 2,′ and 3′; the coefficients worked out to ·78, or roughly 0·80 he thought that with a large weir the coefficient, would be a very large one, probably 0·85.

Mr. Marsh's paper on Increase of Torrent Floods in the Upper Reaches of the Eastern Jumna Canal.

Mr. Davidson—On reading Mr. Marsh's paper I presume that what he wants to do is to try and regulate these discharges so that the works designed may really be permanent instead of requiring extensions.

Mr. Marsh said a good deal of matter in connection with this paper has been thrashed out in the discussion on the Suketar superpassage on Tuesday morning. He wrote this paper because he thought there were so many canals crossing the drainage of the country being designed and he thought the subject might be useful as it shows the troubles from year to year on the Eastern Jumna Canal. That canal had been maintained but with difficulty. Plate No. 48 shows the sketch map in which the Maskhara Torrent appears, and Cautley's Canal which he carried out 70 years ago and the faint channels the torrents that are crossed at different points; the discharges of them are very hypothetical.

Down to mile 8 there has been no great trouble, at mile 8 the torrent used to get into the canal as far as mile 13 where it was let out by flood gates. That arrangement worked well up to 1880, when 300 feet of the canal were cut away, there was a gap 30 feet deep and it was by pure chance that it was repaired and some 10 lakhs of property were saved.

From 1880 to 1889 it was difficult to get money as the Nadrai aqueduct on the Lower Ganges Canal was being rebuilt. In 1889 a fresh dam and regulator was built over the Chapri, that made things all right; in 1894 it was found even this new addition was not enough and the Nowgong weir nearly fell in again; in Cautley's time it was a level crossing; the retrogression now is 30 feet.

In 1894 the waterway of the Nowgong weir was increased 50 per cent., and then it was thought there would be no more trouble. In 1901 another record flood came down and the regulator was completely overtopped; at the Nowgong weir a huge breach occurred. At mile 17 the Executive and

Assistant Engineers saved the position by placing bricks on the top of the revetment wall. This is all in connection with a canal that pays 14 to 15 lakhs in net revenue. He obtained permission to increase the escape at mile $8\frac{1}{2}$ by 50 per cent. and to cut down the Maskhara weir by 2 feet and to place iron falling gates on the lowered crest.

An inspection of the drawing of the Khalsi dam that passes the Maskhara torrent shows that it was completely masked by the silt deposit on account of the original alignment of the canal; some alterations have been since made. The crest used to be 4 feet above the level of the torrent, it has been cut down 2 feet and falling gates of the Khanki pattern put in. These gates are used to guide the water on the side where the shoal is likely to form. These torrents come down at a great pace, and the fear is that the gates might not be dropped in time, automatic gates cannot be used on account of the silt.

This matter has been the subject of much consideration and a very common place arrangement has now been adopted which works well and is suited to the native instinct.

Coolies are left at the dam during the rains and a couple of miles higher up the torrent huts are built; these men are given bombs and when the torrent comes down they shoot them off. It seems an arrangement likely to fail but it is exactly suited to the native instinct and works very well indeed.

Mr. Benton enquired why syphons were not built so as to get rid of the present levelcrossings; he did not think the cost would be greater and the security would be a great comfort?

Mr. Marsh disagreed altogether; he said Colonel Cautley put in nothing but masonry, if he had made these of steel there would be great difficulties now. [Mr. Marsh did not explain what the difficulties would have been]. He said that nothing in the United Provinces has given his predecessors for the past 70 years so much trouble as the torrents, and the experience gained has been recorded in the most valuable book by Sir P. Cautley on the Ganges canal works from which the following is extracted.

Extract from Volume 1 of the Report on the Ganges Canal Works by Colonel Sir PROBY T. CAUTLEY, *K.C.B., F.R.S.*

* * * * * * *

The Nogong dam is a masonry building, constructed across the bed of a torrent, which has a catchment basin of about 56 square miles, 25 miles of which are mountain, and the remainder open forest and jungle country lying at its foot. The dam itself is situated at a distance of 7 miles from the hills, and the slope of the bed of the torrent at the point upon which the building was constructed was $11\frac{1}{2}$ feet per mile. There were twenty-four sluices, of 7 feet width, adapted to the centre of the river's course; the eight centrical ones having their sill or flooring 2 feet, and the side ones having their sills 4 feet, above the bed of the river. The piers of these sluices were from the bed of the river 6 feet in height, and above this point the floods passed over the dam in one unbroken sheet of water.

At the time that this work was constructed, 1828-29, the bed of the river, at the point where the dam was built, and both above and below it, was one uniform slope, with a section of 8 or 9 feet in depth from the surface of the country.

From the rains of 1830 to those of 1834, a constant succession of retrogression of level upon the masonry tail of this work took place. In the rains of the latter year a portion of the tail apron fell and a new tail was constructed partly of masonry and partly of timber and boulders, flanked by hurdles and fascines. This new tail was made on a slope adapted to the depressed level that the bed of the river had at that time assumed at and south of the tail of the dam.

At the commencement of the rains of 1841—that is to say, eleven years after the dam was constructed—the total width of the tail apron, which had annually been receiving an accession of material, was 80 feet on its transverse

section. Year after year extensions had been made, and, as it was hoped, addition had been given to its stability. Early in the rains of 1841, however, a very heavy flood came down the Nogong River: the water, in its passage over this fearful rapid of boxwork (the bed of the river south of the tail being at this time 21 feet *below* the sill of the dam) turned the piling and hurdle work on the left flank, carried away that portion of the tail in its immediate proximity, and was only checked in its career of destruction by the masonry platform, over which it fell in an uninterrupted cascade of at least 15 feet in perpendicular height. The injury was of such magnitude, and the accident had occurred at a period when a succession of floods during the three following months were certain, that there was neither time nor material available for doing anything, further than making a moderate repair; and the only prospect that offered of preventing irreparable injury, was by passing off flood-water down the canal channel, and, if possible, putting the dam out of use for the rest of the season. It so happened that during the rest of the rainy season of 1841 the floods that came down the river were passed down the canal channel with the greatest ease, and, in so far, our arrangements were crowned with the most perfect success.

* * * * * * *

Mr. Marsh continuing said the floor of the level crossing was on a level with the bed of the torrent and that it should be 3′ below, as when the torrent flows the sand moves; while the level crossing becomes a weir.

(The speaker next dwelt on Cautley's method of dealing with silt and on his method of construction having proved correct in the light of the experience gained in later years.)

Another point he wished to remark was that of the discharges of torrent. How are these obtained? There were invariably great differences of opinion, one man estimates the maximum discharge of a torrent at 10,000 cusecs, another at 20,000 cusecs, and so on. He said in the paper that he did not believe in trying to gauge the discharge by volume as he believes it is impossible to do so with any degree of accuracy; the water comes in huge waves, making it impossible to gauge the discharge with accuracy. He believed that a better guide is to try and find a narrow gorge and measure the waterway of a big flood passing through it.

On the Agra Canal there had been a great deal of trouble. Colonel Dyas designed one cross drainage work for 5,000 cubic feet, in 1875 a flood came down discharging 20,000 cubic feet and the syphon was completely turned. It was turned into a levelcrossing.

Mr. Hill said with reference to the discharges from catchment areas; he had always taken the following figures which he had found a safe guide:—

1″	for	50	square	miles.
¾″	,,	75	,,	,,
⅝″	,,	100	,,	,,
¼″	,,	1,000	,,	,,

These were average figures and omitted extremes.

THURSDAY AFTERNOON.

The papers set down for Thursday afternoon were—

27. Mr. Ivon's paper on Mat Branch Extension, Ganges Canal.
28. Mr. Ivon's paper on Injury to the Hindun Dam.
29. Mr. Marsh's paper on Automatic Puddling of Channels.
30. Mr. Kenndy's paper on Distribution of Water by Measurement.
31. Mr. Hill's paper on Distribution of Water in the Deccan.
32. Mr. Hill's paper on Deccan Irrigation Could be Made to Pay.
33. Mr. Hill's paper on Small Tanks in the Southern Mahratta Country.
34. Mr. Hill's paper on Nasik Bandhara Irrigation.

Mr. Ivens' paper on Mat Branch Extension, Ganges Canal.

Mr. Marsh, who presided, said :—This paper had been written merely to show the advantage of doing work quickly. The project was only sanctioned in the rains of 1902 when nothing could be done except to mark the drainages on the maps. In November and December of that year he (Mr. Marsh) examined most of the alignments, and commenced work. By December 1903 such progress had been made, that it was possible to effect a good deal of rabi irrigation, by May 1904 the system was still further advanced. The net result was that the scheme gave a return of 11 to 15 per cent. two years before any revenue had been allowed for in the forecast. The paper shows that the work was a considerable one entailing 52 miles of widening main canal, 40 miles excavation of new branch, 220 miles of distributaries and 26 miles of drainages. The work done comprised 1,585 lakhs cubic feet of dry earthwork, 1 lakh wet earthwork, 3 lakhs of concrete and 5½ lakhs of brickwork.

One of the initial steps was to secure the services of a civil officer to obtain possession of the land. This arrangement saved an immensity of trouble and prevented any interruptions in the progress of the work.

No discussion arose.

Mr. Ivens' paper on Injury to the Hindun Dam.

Mr. Marsh said :—The question raised by this paper is similar to that already discussed in connection with the papers on the Narora weir and Nadrai escape failures, namely the use of double sets of wells without sufficient protection.

The Hindun dam was built in 1874 and consisted of wonderfully strong brickwork and concrete. The Superintending Engineer would not allow any pitching except downstream. In those days they were not afraid of leakage from upstream.

During its construction an officer was appointed Executive Engineer who had no reputation as a scientific man, but he had good common sense, and he pointed out, that the dam was in a dangerous place, just below the railway bridge. When the big flood of 1880 occurred, which wrecked Naini Tal and other places, the discharge of the Hindun river was four times what had been estimated as the maximum and ran 80,000 cusecs. The flood was headed up at the railway bridge and scoured terrific holes, above and below the Hindun dam. The floor was left as shown on Plate No. 50, concrete being absolutely unsupported. The usual remedies of stock ramming, puddling and pitching were adopted. It has worked thoroughly well since, and has never given trouble.

Mr. Johnston said :—That one of the remedies carried out to the Chenab canal weir was to place stone blocks with 3 inches spaces between them filled with puddle to within 4 inches of the top of the blocks, this last 4 inches was filled with concrete; this made the concrete protection of the puddle flexible.

Mr. Marsh objected to blocks over puddle as he thought the blocks go through the puddle; that was the objection to the Narora protection; Mr. Johnston said the blocks at Khanki had been in position for 7 years and had not suffered.

Mr. Benton approved of blocks over the puddle, in the upstream aprons it is necessary to protect the bed. In the case of upstream aprons there is a current of quick velocity and an impervious coat is wanted to prevent anything going wrong with the puddle beneath. In his opinion there is danger of the blocks sinking into the puddle, and to prevent this ballast should be put over the puddle. He doubted if there would be trouble if the concrete were laid monolithic.

Mr. Marsh's paper on Automatic Puddling of Channels.

Mr. Marsh apologised for the egotistical form of this note, but it could not be avoided, as it is an epitome of his own personal observations, and experience.

Up to late years the subject touched upon, was thought a very insignificant one. Quite recently he came across his own personal file in the Secretariat and found in it a remark to the effect, that though he was a good Revenue Officer, he took little interest in Engineering. The writer had formed that opinion, because Mr. Marsh had worried himself in trying to find out the best gradient for distributaries.

Mr. Kennedy computes that the loss of water in channels amounts to 50 to 60 per cent. of that entering the head, therefore Mr. Marsh thought the subject is a very important one, and moreover that the problems of storing extra supply and of carrying volume from one doab to another might be greatly reduced if more were done to economise the enormous losses in existing canals. This has been put very plainly and he drew attention to the second page in which different sections of distributaries resulting from the different gradients are given.

It might be urged that velocity must depend largely on hydraulic mean depths, but there is usually much the same proportion between depths and bed-widths; Mr. Kennedy has given very good proportions for channels, and Mr. Marsh thoroughly agreed with them.

As regards flat slopes, Mr. McLeod has constructed more distributaries than any one in the United Provinces, and he approves of even flatter slopes than Mr. Marsh did, going as low as ·48 feet per mile.

He thought one difficulty in discussing the question of automatic puddling is that the discharges are so incorrect, this he said with all deference to Mr. Maconchy, *e.g.*, take a discharge at mile 3, and again at mile 10 of a distributary, and though no water was passing out of the channel into the water-course in that length, it is quite probable that there would be very little difference, if any, in the two results. This is because the system of taking discharges is wrong. Mr. Marsh hoped that the proposal to grade with flat slopes would be criticised freely; his idea is to give the water a chance of making a watertight perimeter. Where a branch takes off from the main canal, careful regulation should be employed so that the water enters quietly instead of tearing up the bed. It will have the velocity given by Mr. Kennedy's diagrams for a mile or two, then after a good start no trouble will be experienced from silt.

He did not think that a slow velocity induces weeds as is commonly believed. In Rohilkhand he found channels full of weeds, although the bed slopes ran as high as 4 feet and 5 feet a mile.

Mr. Bion can testify to the improvements in keeping channels free of silt introduced on the Eastern Jumna canal; they have been very successful and have been the means of a large saving of expenditure.

Mr. Marsh said Mr. Laurie, Executive Engineer, sent the following remarks on the subject:—

Proofs of Automatic Puddling, collected by Mr. A. C. LAURIE, Executive Engineer.

Approach channel, Baldi aqueduct.—This channel is 700 feet long and in very high embankment nearly all the way, its maximum height being 20 feet above ground level. It is composed of almost pure gravel and small boulders, with outer slopes at 1 to 1 pitched with boulders. Water first admitted towards end of August 1903, when the loss actually calculated from discharges was 27 per cent. It was run almost the whole of September, but there were

few muddy floods during that month, and the diminution of percolation was 4 per cent. or 5 per cent. only. On 2nd April 1904 a freshet came down, and advantage was taken of it to run a supply through this channel, and the loss immediately fell to 9 per cent. It has run continuously since then, and discharges taken on 6th June showed a loss of only 7 per cent., and one taken on 27th July current year gave 1·8 per cent. loss. The process going on is no doubt one of conglomeration, of which numerous evidences, in the existence of huge blocks of a sort of natural concrete, are to be found almost everywhere in the Dun torrents.

Balawala and Nathuawala minors.—The first mile of these channels runs in an old excavated channel, which was given up as hopeless some 12 or 15 years ago. The bed and sides consist of boulders, from a cwt. to a ton in weight. The original bed had a very rapid slope, which prevented any deposit of silt; this was flattened by introducing falls at every hundred feet or so.

On first admitting water in June 1903, a discharge of 18 cusecs did not reach beyond the first furlong for 3 days. The process of natural puddling was all this time going on, and gradually the water reached further and further. By the 25th August 1903 the loss over the whole length of 9 furlongs, with a discharge of 18 cusecs at head, was only 24 per cent. This channel has been run, whenever supply admitted of it, during the *rabi*, and again since the rains have broken. The loss in the total length of 9 furlongs is now only 9 per cent. In addition to filling up the interstices under ground, a deposit of one foot thick has been formed all round the wetted perimeter. The channels were dug one foot wider and deeper to allow for this deposit.

Lakhanwala and Fatepur minors.—These channels are now quite watertight.

Mr. Kennedy thought the Punjab and United Provinces Engineers generally agreed; but that the latter go further than the former.

Mr. Preston said that at an early stage of the discussion he would like with Mr. Marsh's permission, to circulate the section of a channel he has recently sent up to the Government of India for sanction. Mr. Marsh has in it carried out his theory in the case of a large canal carrying 1,700 to 2,000 cusecs. The interest in the section is the number of 1 foot falls which Mr. Marsh has introduced, and this is certainly an exceptional grading for a large canal; it certainly shows that Mr. Marsh has the courage of his opinions not only for distributaries, but for canals. Besides the lining of the channel with silt there is another reason for which this was done. It will be seen there is an extraordinarily shallow depth of clay, it varies from 4 feet at the head of the canal to 7 and 8 feet lower down. Mr. Marsh wishes to keep the grading of the bed within the clay so as not to cut into the sand, to do which would increase the percolation. Mr. Preston was bound to say he had never seen any large branch of a canal designed on similar lines, and he thought it exemplified Mr. Marsh's contention better even than the papers itself.

Mr. Nethersole said he drew up the project; the slope given is simply one that will provide velocities that are considered proper for the main canal; canals that have been made since with slower slopes are found to work satisfactorily.

The reasons for adopting the series of falls were: firstly the one Mr. Preston had first given, *viz.*, that there was great objection to going through that clay anywhere, and secondly because outside excavation to make up banks was avoided. One of the objections raised to the canal under consideration was the high spring level.

Mr. Marsh said he had plenty of instances to justify the grading proposed; the Agra canal for 32 miles had a grade of half a foot in a mile, *i.e.*, ·5 in 5,280 only and it is in perfect condition, and the distributaries taking out of those 32 miles are not troubled with silt at all, because the canal is going smoothly and is not tearing its bed and banks and providing silt to deposit in the distributaries. Below mile 32 there is a good deal of silt clearance. In the Eastern Jumna canal headreach the water goes over boulders, a two-anna bit can be seen in 5 feet of water; when it gets into reaches with rapid slopes of 1 foot and 18 inches a mile, the water becomes very dirty showing the amount of stuff it has scoured on the way. Mr. Marsh believes that a great deal of the trouble in canals is due to the water going too fast.

On the question of Government taking charge of small channels Mr. Nethersole wished to say a few words. In the Northern Division there were four zemindari watercourses, which were graded at slopes of 10 feet

and 12 feet a mile; the aggregate discharges were 42 cusecs; they were taken up and converted into Government channels by the interpolation of shallow falls. He went very carefully into the statistics of the irrigation they were doing both before and afterwards, as well as the discharges and found there was saving in volume, of 40 per cent., and a considerable increase in the area irrigated.

The minors also improved, as eventually the channels got lined with a waterproof coat; but the chief thing has been the economy in the water.

Mr. Benton agreed generally on the point under discussion, but thought it should be proved that the grading proposed is cheaper than that usually adopted before it could be said to be better.

Referring to the silt in channels with flat slopes, Mr. Bion said there is the Baruli distributary in which for $2\frac{1}{2}$ years the first two miles had a slope of 1·60 in 5,280 dropping to 1·2 in 5,280 and then to ·8 in 5,280. Up to the time he left, it had run for $2\frac{1}{2}$ years and there was no clearance whatever either at the top or the tail.

Mr. McLeod stated that since the remodelling had been done the cost of maintenance was very much less, and percolation had entirely ceased.

There was no discussion on Mr. Kennedy's paper on distribution of water by measurement.

Mr Hill's paper on Distribution of water in the Deccan.

Mr. Hill in introducing his paper on distribution of water in the Deccan, said:—It has been argued that the distribution of water from a tank is not the same as from a river, where the supply is flowing; it seemed to him that the principles of distribution are the same.

He did not think the present Bombay practice is right, they don't distribute the water unless it is applied for; so that if it is not all applied for it is kept in the tank and wasted. He maintained that the whole volume of the water in the tank should be used every year; the system of distribution should be worked out in precisely the same way as from a river, the water should be allotted for certain crops, whether it is used or not, the people would soon get used to the system; an economical system of distribution should be provided which should be worked to. He said the people do not apply for the water, because they are not confident that it will be there. No system of watercourses is provided in Bombay. There is a keen demand for water for sugarcane, but for the irrigation of cane the cultivators have to expend large sums; and until they are certain, they will get the water they won't lay out any money. The charge for sugarcane is up to Rs. 40 per acre, and still there is a greater demand for water than can be supplied.

Referring to the paper on Bandhara irrigation in Nasik, Mr. Hill said these works were in existence before the Public Works Department was created. The supply from them is not nearly as good as from tanks.

Mr. Marsh enquired if it would lead to an extension of irrigation, if the water rates were cheaper.

Mr. Hill.—I don't think it would.

Mr. Marsh.—We want to make reductions for rice and sugarcane.

Mr. Hill.—It is a great mistake to reduce rates for rice.

Mr. Marsh said he had just proposed an alteration of the existing rates on the United Provinces canals, there is a splendid volume of water available at Narora, when the snow melts in the hills in May; but still there is a very small return from kharif irrigation on the Lower Ganges canal. Since indigo went out of cultivation there has been no corresponding development of cotton, rice or maize, except in a dry year, when the monsoon fails. He was quite sure that the revenue will increase immensely if the rates for sugarcane and rice, and for the kharif crops generally are reduced on this canal. The scheme has been approved by the Board of Revenue, and the Lieutenant Governor. A demand for water during the rains will be a great gain, because during the floods the muddy Ganges water can be passed into the distributaries; the water is ordinarily very clear at other seasons and does not provide the sediment which is so valuable for staunching the channels.

Mr. Preston said :—It stands to reason, that the rates imposed must vary for the differing circumstances of different canals. On the Western Jumna canal in the Punjab the Lieutenant Governor recorded a note in 1896 in which he said that it would be proper to raise largely the rates for sugarcane, because the large quantity of water required for that crop hampered the rabi irrigation.

In the Karnal and Delhi districts this crop has been said to be the sheet anchor of the cultivators, and yet they only pay a rate of Rs. 8. When he was Chief Engineer he had proposed to run it up to Rs. 12 as in that particular case, it is desirable to choke off its cultivation to a certain extent so as to set water free for the extension of rabi cereals which benefit so many more of the cultivators. He had heard sugarcane described by a cereals engineer as "a noxious weed." The case of the United Provinces is different. In that case there is ample water, but no demand added to which it is desirable to bring the silt in the channels. It therefore seemed to Mr. Preston it was impossible to generalize or to say that the rates charged in one place were too high or too low because they were different elsewhere.

Mr. Visvesvaraya said that near Poona a prohibitive rate for sugarcane had been put on, but the conditions prevailing justify it.

Mr. Hill remarked that the works in the Deccan are protective, but they do not get full credit for the benefit they really are. Thus when they are made, the value of land goes up largely. Land originally worth only Rs. 25 an acre has been valued at considerably over Rs. 100 since a Government irrigation work has been made, and he thought there ought to be some way by which the canal or tank could get credit for this increase.

Mr. Marsh enquired whether some action will not be taken at the quinquennial settlement, but was informed that the settlements in Bombay are for 30 years; continuing, he said in the "precarious" tracts of Bundelkhand, a system of quinquennial settlements has been introduced whereby a share of the profits of the land owners from new works which they obtain by increased rent of land will come to Government, when the value of the irrigation has made itself felt. The whole or some portion of this increase in land revenue will be credited to the works. A reference to the Irrigation Revenue Reports shows a large item credited to the indirect receipts of the canals amounting to something like 30 lakhs in the United Provinces. The Lieutenant Governor of those Provinces has devoted much attention to this point, and has decided that in the case of future small protective schemes, it is to the indirect profits in the form of stability of land revenue, and possibly its enhancement, that credit must be looked for.

Mr. Preston thought that was not quite the point. He said that when land was taken up on the Swat river canal in 1879, not more than Rs. 5 per acre was paid for it. Now the value has run up to over Rs. 150. Mr. Hill considers that the Government works should obtain credit for some share of the increase of Rs. 145 which has accrued to the land owner. The question is how is it to be got? Mr. Marsh thought it would come in at the quinquennial settlement, but Mr. Preston said the Government does not, as far as he was aware, get any share in the increased capital value of the land.

Syed Jaffer Hossain submitted the following note on a similar point.—

In Gwalior State there are three kinds of small tanks :—

(1) Submerging tanks;

(2) Submerging tanks with rice fields outside them;

(3) Small reservoirs.

In depressions, where there are ridges on two sides, low bunds, with scouring sluices, are erected from ridge to ridge to hold water in order to submerge the land on the upstream side. In the month of October the tank water is let out through the sluice to the neighbouring drainage. The land which had been under water is then sown and yields very good rabi crops without any further watering or manuring. The manure is supplied by the cattle which graze over the catchment area throughout the year.

These tanks cost very little, and yield a very large profit on the outlay, sometimes when the gradient of the ground is not very steep the crops yield up to 20 per cent. on outlay.

2. In places where there is suitable land for rice cultivation below the bund, one or more sluices are provided to irrigate the rice fields. The tank water gives three advantages to the rice crop (1) manure; (2) a crop of grass; (3) irrigation.

The rice fields are surrounded by banks from 1 to 2 feet in height. After the first shower, when the tank has filled sufficiently, the cultivators plough the fields and fill them with tank water, and keep them under water for 4 or 5 days, so as to drawn all the coarse grass. Then seed is sown, and after 3 days when it is about to sprout the banks are cut, and the water drained off. The whole process takes from 7 to 10 days. During this period, if there is no rain the fields are kept brimful with water from the tank, to supply the deficiency caused by evaporation and percolation.

If the rains are favourable and regular, no more irrigation from the tank is required until October, when one or two waterings are given to bring the crop to maturity. In October the balance of the storage is let out through the sluice, and the submerged area yields a very good rabi crop without further watering.

In years of scanty rains, the rice crop generally fails, but the rabi crop is assured. In a year of drought no rice is sown, and the rabi crop is precarious except in the lowest part of the bed of the tank. These reservoirs are also very useful for raising the spring level in the wells. In rocky ground, the spring level is often so low, that well irrigation is impracticable, but in the course of three or four years after the construction of a tank, the spring level will be found at a reasonable depth. The least catchment area which is required for a very small tank of this kind is one square mile, provided that its soil is impervious, and the gradient is steep; otherwise five square miles will hardly be sufficient to fill a tank having a submerged area of 500 acres. Five inches of rain with an intensity of ½ inch per hour, will suffice to fill a tank of this size.

3. The third kind of tank are regular reservoirs. In places where the sites are favourable for impounding a large quantity of water on unculturable ground, reservoirs are made with comparatively high bunds, and the water is stored to irrigate rice and rabi crops, through small field channels.

There is yet another kind of tank. The country being hilly the rivers and drainages are very deep and a large area of land is consequently covered by ravines formed by the rush of the surface water into the drainages, this is denuding the land yearly of its good soil and converting it into bad broken ground.

Sir Michael Filose, the Chief Secretary to the State, has constructed a number of bund across the drainages so as to impound water in the ravines. In the first few years very little land was submerged, but in course of time the ravines became silted and the water spread over the adjacent land and gradually reclaimed a large tract of the ground. Thus the cutting back action of the ravines was totally stopped. His Highness the Maharaja Scindhia takes a most practical and useful interest in irrigation works in his country and has lately amplified this system to a considerable extent.

Exact figures cannot be produced to show the productive value of these tanks, as no records are kept. His Highness the Maharaja wishes to encourage the cultivators to fully utilize these tanks and has been pleased to command that no water rate should be assessed till the next settlement.

FRIDAY MORNING.

The papers considered on Friday morning, 9th September, were—

35. Mr. Kennedy's paper on Remodelling of Irrigation Distributaries.
36. Mr. Johnston's paper on Remedies Being Carried Out to the Siswan Superpassage, Sirhind Canal.
37. Mr. Kennedy's paper on Lessons to be Learnt from Sirhind Canal Silt Troubles, with note by Mr. Gillmon on Arrangement of Gates at Rupar Head Regulator.
38. Mr. Kennedy's paper on Value of "N" in Kutter's Formula.

Mr. Kennedy's paper on Remodelling of Irrigation Distributaries.

Mr. Marsh, with reference to what has been said about the necessity of increasing our staff, if the large village watercourses are taken over as Government minors, said he thought any Executive Engineer would say that the work has decreased since this has been done. Speaking for himself, he must say he would rather hold a division now than 20 years ago, when there were very few minors and the loss by closing outlets periodically was considerable and there were constant magisterial trials. There are very few instances now of fields being starved for want of water at the tail of a watercourse.

He had read the paper on the result of Mr. Kennedy's remodelling of the Western Jumna canal; it showed the troubles that resulted from the remodelling; he thought every report should deal with the disappointments as well as with the happy results that follow from improvements.

Mr. Kennedy said the report referred to was premature, being written before the work was completed.

Mr. Marsh, continuing, said in some of the minors the water evidently did not get to the tail and yet too much was let in at the head; he thought that was a result not of Kennedy's system, but of the improvement not being sufficiently nursed at the beginning. Probably Mr. Kennedy was transferred or there was some reason of the kind; alterations of this kind require a great deal of nursing and watching in order to eliminate the angularities and faults. Mr. Kennedy has fixed the factors much higher than he (Mr. Marsh) would do; on the Western Jumna canal it is taken as 150 acres per cusec. On the Eastern Jumna canal the distributaries of which have been remodelled, it has been taken at 110 acres per cusec, but then he found that the 150 acres is for both seasons; so it would come to the same thing.

As regards discharges, the only thing he had to say was, with all deference to Mr. Kennedy who is a great mathematician, that he had very great misgivings as to the accuracy of any discharge.

He did not know whether any gentleman present had ever taken a discharge above a trifurcation; he had done so, both with rods and floats and had always found Bazin's coefficient correct. Mr. Kennedy in paragraph 6 of his paper had advised the construction of profile walls, Mr. Marsh did not think there was anything on which so much money had been wasted as on these; it is doubtful whether there is any certainty as to the actual discharge required; in a given channel it may be necessary to increase or decrease that allowed at first, then all the calculations are thrown out, and if profile walls have been put in, it is impossible to alter beyond a certain point. Cultivation may change greatly on a new distributary and again the calculations are thrown out.

Mr. Kennedy said the paper under discussion only applied to remodelling old distributaries, and there profile walls had always been found in the Punjab extremely useful; he would not put them into any new distributary.

Mr. Marsh thought this should be clearly shown or it is apt to be misleading. Referring to the remark in the paper regarding how the outlets should be built, he said it was a subject in which there had been a great deal of trouble and the United Provinces' engineers had come to the conclusion that anything in the form of masonry would not do.

He said they now use long castiron—pipes, and find them cheaper than anything else; they can be bought in the market 10′ long and can be made watertight; they can be put in at any required level, and if anything goes wrong with them or a change is required it can be effected with ease. He added that since they have been in use there has been no interference in the outlet by the villagers. Mr. Kennedy has touched on the subject of dividing fields into plots. Years ago, Canal Engineers worried themselves a great deal about them, but he found the distributaries wanted so much remodelling that he had stopped it.

Mr. Kennedy agreed that castiron pipes would be very good, but very costly.

Mr. McLeod said that he had made outlets of from 4″ to 6″ diameter of castiron pipes and that he believed the difference in cost of masonry and cast-ron pipe outlets was Rs. 300, for a whole system in favour of masonry.

Mr. Nethersole said that what struck him after reading Mr. Kennedy's papers and others on the subject such as that on the financial results of the Deoband branch, Upper Ganges canal, and the other on certain drainage cuts, is that after all the science of irrigation has not advanced very much. A great advance has no doubt been made in the distributary systems by the abolition of *tatils* and that the running of channels alternately with their designed full supplies has led to economy. He did not think we had profited as much by experience as we might have done. Thus, on the Jamaro canal, which was designed and constructed comparatively recently, the same mistakes are found as have been recognized and written about on the Upper Ganges canal; he referred to the steep bed slope and consequent scour. It is a very great pity as the same bad results have necessarily followed.

Passing on to watercourses, so far he thought no advance at all had been made. He was not sure that the matter had been gone into in the right way; desultory experiments have been made as officers have only been able to do them in the midst of a great deal of other work; nothing comprehensive has been undertaken. If experiments in these directions were made systematically under a trained man, some definite information would be obtained as to what loss in the present efficiency it would be possible to save, he thought such experiments would be well worth their cost to Government.

He had puddled a watercourse as an experiment. The difficulties he found were in the observation of discharges in such a small volume of water; it seemed to him that is the difficulty in deciding what advantage is to be got from making channels impervious.

Next as regards Kiaris, when he first came to the country it was an important part of his duty to write about the difference in the increased duties in certain fields; that has been since given up, and he thought that until the distribution is in a more efficient state that part of a canal officer's duties might well be dropped.

Recently, he made the whole of his revenue establishment undertake a very practical experiment, the orders were for each man to go to a watercourse, and having selected a dozen fields of equal size or a single field divided into two equal parts, then when the head on the outlet was more or less constant to make observations as to the irrigation of one field with, and of one without, Kiaris. Many observations were made and the net result showed a loss of water of 30 per cent. in the fields in which there were no Kiaris. He thought that this loss is entirely avoidable.

He wished Government would sanction an experiment on a given minor with a view to testing what duty can be got out of a given discharge by an officer actually doing the irrigation himself. This would give positive proof what volume could be recovered of the water at present lost.

He would put an officer on special duty. If the experiments were carried out systematically throughout a whole year or harvest, it would be seen what duty could be got out of the water.

Mr. Preston said he was glad to be able to inform the Conference that at his suggestion the Goverment of India have already done the very thing which Mr. Nethersole asks should be done and that this was the main reason for Mr. Kennedy's transfer from Bengal to the Punjab.

Mr. Kennedy has been given an absolutely free hand as regards the establishment and money required to ascertain —

(1) the loss which Mr. Nethersole complains of:

(2) whether in any way he can make the watercourses and subsequently Government channels watertight.

Unfortunately Mr. Kennedy's return to the Punjab took place just at the beginning of the hot weather; and it is believed he has not been able to do much as yet but much may be looked for next cold weather. Mr. Preston was thoroughly confident that the experiments cannot be in better hands and that by the autumn of 1905 engineers will have the information which Mr. Nethersole thinks they should possess.

Mr. Nethersole agreed that the experiments could not be better entrusted and Mr. Kennedy thought similar observations might be done in the United Provinces.

Mr. Preston did not think so. It seemed to him it would be a mistake to have too many experiments, besides which establishment is desperately short. Certain results will be obtained in the Punjab and from those other Provinces will no doubt be able to deduce what will suit their needs.

Much satisfaction was expressed by the meeting at the action of Government in this matter.

Mr. C. A. White thought it would be an advantage if, as a result of the conference, some standard practice were decided on for calculating "duty of water."

Mr. Buckley in his book on Irrigation states: "The duty of water is the area of crop which can be matured by a given quantity of water."

The unit of quantity of water is usually taken as 1 cusec, but the base of the duty should be noted, *i.e.*, the number of days in which the crop is matured. It is rarely noted in how many days one watering is given or the number of waterings.

Again in calculating duty one person will include every day of the irrigating season whether water was taken or not, while another will count only those days on which water was taken.

In Bengal it is most usual to calculate the duty over the whole season, taking every day whether water was taken or not, but the duty is also calculated for one watering of 15 or 20 days at the time of keenest demand. Again in some cases the total discharge at the head is taken and in some that utilized only.

It appeared to Mr. White that the unit for the base should be either :—

(*i*) a fixed arbitrary number such as 1, 10, 15, 20, 30 or 100 days, whichever may be decided upon, or

(*ii*) the number of days required for one watering—

(*a*) for rice, this might be the average least number of days in which 1 cusec would irrigate the area;

(*b*) for rabi, either as above or the total number of days in the season divided by the number of waterings found necessary to mature the crop, say $\frac{120}{3}=40$.

It might be possible to fix the bases for rice and rabi for each system of canals.

The following rules are suggested.

"Duty of water" to be the area of crop which can be irrigated by 1 cusec in X days for rice and Y days for rabi.

The duty to be calculated on the water utilized.

It should be clearly stated whether the duty is calculated on the discharge of the head sluice of the canal or the head sluice of the distributary, and unless one fixed base is adopted for the whole of India, the value of the base must invariably be noted.

In Egypt the duty is taken as the number of cubic metres required in 24 hours for each *feddan* (about 1 acre) of land*

Mr. White understood that in the Punjab the rule is to take the duty as the area of crop which would be irrigated by an average supply of one cusec running full time.

Mr. Kennedy said in the Punjab the rule is to take the duty over all the days the canal is open during the season or crop, he thought this is, perhaps, as good a method as any, but all are imperfect, as the rain fall, duration of flow and the number of waterings given to each crop are all important factors. Theoretically the best unit would be the value of "*delta*" or average depth of water laid on for *each* watering, during the crop; but not knowing the number of waterings this is impracticable.

Mr. C. A. White said the term "full supply factor" used in the paper is new to him; he understood it meant the duty modified by "tatils" and loss by absorption and is usually applied for the discharge required at distributary heads, and of course varies on each canal.

Mr. Horn used to say that the Bengal Irrigation Officer is practically concerned with one crop only, *viz.*, rice. The critical period for rice cultivation is towards the end of September and the first 10 days of October. Last February, he (Mr. White) was informed that the demand for water for transplanting is sometimes as great as it is in October. It may be so now, but it was certainly not the case when he was on the Sone canals 15 years ago. In designing a new system of canals for rice cultivation in Bengal, no one would dream of designing the canals for a higher duty than 50 acres per cubic foot of gross discharge. In the Sone the duty at the outlet is taken at 80 acres for a period of 15 days, during five days of which the outlet remains closed. In the Midnapore district the duty is nearly 150 acres. If the Behari cultivator would learn to do away with "Nigar"† in the middle of September, a duty of 80 acres per cubic foot of gross discharge would be possible. In Bengal the rabi duty has no value.

Syed Jaffer Hussain thought much good might be done particularly in regard to economy of water if an attempt were made to teach the cultivators, who are quite ignorant, improved methods; some agricultural books have been introduced into village schools but in these nothing is said about irrigation.

The Opium Department are endeavouring to do so; they have an annual gathering of opium cultivators; appoint one man as the head and then give instructions as to how to cultivate opium and encourage this by giving them rewards.

If the cultivators knew how much they might benefit themselves by using canal water economically, and if they were directed in these matters by zilladars and other officers from time to time, they would improve in their methods.

He also thought that the shutters of outlets should have some arrangements of locking which would prevent interference by cultivators and others.

**Note*—*

S. Depth in inches $= \frac{\text{Base}}{\text{Duty}} \times 23{\cdot}8$

V. Volume in cubic feet $= \frac{\text{B}}{\text{D}} \times 86{,}400$.

X. Discharge in cusecs $= \frac{\text{Area}}{\text{D}} = \frac{\text{A. S.}}{\text{B.} \times 23{\cdot}8}$

† "It is a custom among the cultivators that during the period known as the Uttar Phalguni Nakshatra, extending from the 11th to 24th September, the water used for irrigating the rice (whether canal or rain water) is let off or drained from the fields. The lands are then dried. This drainage water is known as nigar. It flows from land on a higher level to adjoining land on a lower level."

Mr. Kennedy observed that by the Punjab system outlets are never closed. Whenever a distributary is open at the head all the outlets on it were entitled to take water if they desired to do so.

Mr. Preston wished to make one remark with regard to what Mr. Nethersole said as to there having been no improvement in the matter of watercourses; he joined issue with him on that point.

The minute system of distributaries to the new villages formed out of crown waste land in the Punjab had been fully described in a paper published in Volume 153 of the Proceedings of the Institution of Civil Engineers, but even in the case of old villages he thought a great deal had been done in recent irrigation schemes by accurately levelling the whole country, and by the Engineers aligning and grading the watercourses to be subsequently dug by cultivators. He therefore did not think Mr. Nethersole was right in saying no progress had been made in this direction.

Mr. Nethersole said he was not referring to the alignment; but to absorption losses.

Mr. Benton asked Mr. Kennedy to explain how he would arrive at the full supply factor in the case of a new project.

Mr. Kennedy replied that an assumption must be made that there is so much water, that it has so many days to run and the full supply factor must be deduced accordingly. In both cases (*i.e.*, calculating for one crop or for both) there is a certain amount of assumption; the assumptions as to the amount or relative proportion of *kharif* and *rabi* may not prove correct, as in the result that mostly depends upon the people and local conditions; on the whole he would say it will be best to simply assume that so much percentage of the commanded area is to be irrigated during the year, and leave the question as to how much of this will be in one crop and how much in another to the cultivators.

Mr. Johnston's paper on Remedies Being Carried Out to the Siswan Super-Passage, Sirhind Canal.

Mr. Kennedy said the Siswan superpassage has given an increased amount of trouble and anxiety; should it come to grief, the whole Sirhind canal would have to be closed for probably two years or so.

The down stream 50 feet of the arches have sunk bodily from 3 to 6 inches, and threatened to cause the collapse of the arches. For a long time the cause was unknown, but now there is no doubt, but that it is due to the "pressure-head" of the subsoil water causing springs and sandblows from under the floor and inverts on which the whole structure is built. Since Mr. Johnston's note was written more information has been collected as to how this underground pressure acts, by observing the level of the water inside stand pipes, fixed at the nose of each pier, abutment, and also outside the canal under the torrent bed. The results have all been plotted on a diagram (Pl. No. 56) of which a few tracings only are at present available; and in order to understand the results the following notes should be read :—

The diagrams showing the heads of pressures under the foundations, which have been completed since Mr. Johnston wrote his note, require further explanation.

Take the torrent first the bed of which is shown as a hatched line at R. L. 878·00, in a continuous diagram of daily records. The black patches above bed shews heights and duration of floods in the torrent, and it will be seen these only last short periods. The dotted line below the bed shews the levels at which water stands in a hole dug in the bed of the nala close to the deepest channel, *i.e.*, where the flood lasts longest. To the side of this, at the torrent edge, the depth is usually about 2·0 feet lower; but neither of these are real spring levels, merely the seepage, from the floods trying to find its way down to the subsoil water. This it does very slowly as shown by the diagram, but rises at once when the next flood occurs. If a tube well be put down close alongside of one of these holes, it shews a very much lower *real* spring water level; 10 or 12 feet lower, two such tubes have been recorded since the 13th July and are shown on the diagram as "left well" and "right well" as observed on that date, and at every subsequent seven days' interval. The position of these two tubes is about 150

feet back from the abutment and nearly in the line of the stand pipes at the down stream nose of each of the six piers and the two abutments; of which the pressure heads are also shown by the same line. It will be noticed that the real spring water level outside the canal, has risen in the left well (*i.e.*, left of canal looking down stream) from 865·91 on 13th July to 869·66 on 31st August; or nearly four feet; and the right well from 865·08 to 870·91, or nearly five feet.

The chain dotted line shews the canal supply level; the canal bed being shown by hatched line as 854·43.

It will be observed that as long as the canal is running fairly full (about 10 feet depth the head in the stand pipes is always about one or one and a half feet *above* canal level, and this even on the 31st August, when the spring water level outside the canal had risen 4 or 5 feet. In other words the upward pressure under the floor seems to be nearly or quite independent of the spring water level outside the canal, though from both sides subsoil water drains into the canal. The pressure in the stand pipes seems to have its source from deep down under the floor, and in fact this head may be sometimes a little higher than the spring level just outside; (see for example July 13th and 20th), though when the outside level rises it is considerably lower.

Immediately, however, the canal supply falls, the level in the stand pipes also falls which must mean an increase of spring from underneath the floor, partly through the cracks that still remain, and partly on the canal bed, up and down stream. What is chiefly to be feared is of course the *difference* between the head in the stand pipes, and the canal level; this increases rapidly as the canal level falls, and constitutes the force tending to lift the floor and cause sand to blow up. With a full canal this head is only one, or one and a half feet, and with an empty canal, at the end of a long closure (see May 25th), with one foot of water in the bed, it is from 4 to 5 feet. This may be taken as the utmost safelimit, seeing that the concrete floor put down last year is only 2 feet thick, and would only need about 4 feet head to lift it bodily. To show the effect during the time the canal is being closed off a separate diagram has been drawn out, and though the canal level was only lowered about 5½ feet in 9 hours, yet the level in the stand pipes sank so much slower than this rate, that at the end of that time the head under the floor had risen to the danger point of nearly 5 feet, from its original figure of under 1·5 feet. This shews the extreme danger that would arise from any very sudden closure of the canal, by dropping all, or nearly all the head gates at once. Thus, if it were possible in an emergent closure to lower the canal level in two hours from 10 feet depth down to say 3 feet; the pressure head would probably be somewhere about 7·0 feet.

It will be seen that the pressure at the different piers is by no means the same, and the differences increase rapidly, the lower the canal is, *i.e.*, the greater the pressure head. The lowest pressures are at pier No. 1 from the left, and at the right abutment; and the reason can only be that there are more springs finding an exit there than elsewhere. Possibly pier No. 1 is connected underground by an old drain pipe left underneath, and leading towards the new spring which burst up suddenly last May, down stream from the line of piles.

Mr. Marsh said he had read this paper with great interest and desired to throw out the suggestion that the cause of the trouble seems to be the inequality of the spring level; it rises and falls, and he would suggest puddling the canal upstream; he supposed half a mile could be puddled for Rs. 30,000; and a great deal more than that must have been spent.

Mr. Kennedy did not agree, he said the trouble is due to the pressure level beneath the foundations and that it would be useless to puddle the bed as the pressure comes from below the work.

Mr. Marsh observed that the pressure drops when the canal is closed which shows the canal has something to do with it.

Mr. Benton.—Yes, an inverted filter downstream.

Mr. Kennedy pointed out that as a matter of fact the pressure under the floor is higher than the canal water level always, it falls with the canal but keeps above it.

Mr. Marsh enquired if there was any record showing original spring levels and was told there is not, but it was much higher than it is now, because the canal acts as a drain.

Mr. Kennedy's paper on Lessons to be Learnt from Sirhind Canal Silt Troubles with note by Mr. Gillmon on Arrangement of Gates at Rupar Head Regulator.

Mr. Kennedy said about 1893, the Sirhind canal threatened to silt up bodily at the head, many remedies were proposed, some were carried out and

certain experiments on silt were kept up from 1893 to 1898; the results are not generally known, and do not assist much in a solution; chiefly because all the finest mud or clay sediment, which does more good than harm, was included in the observations while all that really matters is the sand. The main result which Mr. Kennedy has been able to deduce is that most sand is carried, not in the rains, but in the melted snow water before the rains.

A classification of the various kinds of sand is also proposed; based on velocity of fall in water; and a form of sand-separator, utilising the same principle is given on Plate 58.

An analysis of various sands in the form of a diagram is also given, *vide* especially the results showing that the sand in a river bed is really finer far away from the hills.

The principal interest in this paper, however, will probably be thought by most people, to lie in the proof, that a raised sill at the head of a canal is by itself of no use in excluding silt; but there seems no escape from this conclusion; and it is one which many people will think might have been expected.

An inspection of the model of the canal head under sluices and regulator in the room, shows that the chief peculiarity in the latter is its high raised masonry sill and a moveable gate sill rising above this with the same idea of excluding silt. Mr. Gillmon has given a full description of these.

Mr. Benton fully agreed with Mr. Kennedy that it is most desirable to take off from a comparatively slack waterpool in the case of canal head-works in very sandy rivers. He did not think it would be advisable to dispense with a high crest wall; in his opinion it is very necessary. And Mr. Kennedy admitted that wherever the levels admit, it is certainly advisable to put in a crest wall, in fact it will usually be necessary for other reasons.

Mr. Johnston referring to the remark in the paper that raising the sill did no good, thought the statement might be put in another way. Raising the sill by itself did no good, *i.e.*, that taking fast running water over a raised crest means that just as much silt is taken into the canal as if no raised crest was there. As a matter of fact, however, having the raised crest enables the still-water pond to be formed in front of the regulator if the undersluice gates are kept closed. The raised crest to the regulator together with proper regulation seems to have got over the silt difficulty in the main line of the Sirhind canal. It had been found at the head of the Sirhind canal; it is absolutely necessary that the regulation should be done at the right flank of the weir as much as possible. The Rupar weir is not a long one. The total length including the undersluices is 2,399 feet; so that if regulation is done at the left flank of the weir the still water pond from which the canal is fed would be somewhat disturbed; and more silt would be drawn into the canal.

He believed he was correct in saying that the silt difficulty is considerable at the headworks of the Sone canals in Bengal and he would like to ask if the improvement to the undersluices suggested on page 42 of Mr. Buckley's book, namely, dividing the undersluices into two parts by means of a long masonry groyne with sluices at the upper end of the left portion: so as to make a still water pond in front of the canal regulator had been carried out?

At Rupar the water is held up 15 feet at the undersluices against 10 feet at the headworks of the Sone canals. If Sone canal undersluices were raised and higher shutters provided for the weir and the canal regulator provided with a raised crest like that on the regulator at Rupar, then he thought the Sone canals could be supplied with fairly clear water. And the silt difficulty overcome as it has been on the main line of the Sirhind canal.

Mr. Stawell said, Mr. Buckley and he came to the conclusion that it would be necessary to draw the supply off as much as possible from still-water. The Sone gates are in two parts; as the flood rises kurries are put in on the top of the lower gates, as it rises farther the undersluices are opened, and when the river gets to a certain level all the weir shutters are dropped,

and the canal is closed and is not allowed to be opened again until at least six of the undersluice bays are closed.

Two years ago there was a large demand for canal water; it was impossible to get the canal shutters up and when I did so I got 2 feet of silt in one day.

I said to Buckley I would not be responsible unless he gave me authority to keep up the undersluices as far as possible.

I keep up the weir shutters until there is one foot of water going over the top of them.

Mr. Kennedy said, if the canal full supply level happens to be very much lower than the river level as headed up by weir, a high crest must be raised, otherwise the waterway would be too great; if the canal bed and water level were high, a low crest only is wanted. The ground silt is mostly deposited high up in the still pond. He agreed that it will usually be built in all head regulators, but it is not essential, as far as the silt question is concerned. As a matter of fact, it did no good as rather more silt went in after raising the crest than before. The essental point is to have a comparatively stillwater pond in the river, from which to draw off supply. If the heavy silt is not deposited in this, and gets carried up to the crest wall, it will go over it and be carried with the water into the canal.

He did not believe that if the sill did not exist, the silt would necessarily be swept into the canal.

If the silt is deposited in the stillwater pond (sill or no sill), well away from the canal head regulator only clear water can possibly reach the regulator, and enter the canal. Once the pond gets silted up, or the velocity of approach is sufficient to carry forward the silt to near the canal head, a sill will have no effect in keeping sediment out of the canal.

Mr. Kennedy's paper on Value of "N" in Kutter's Formula.

Mr. Benton said, it was found in the Bari Doab canal experiments, that the figure worked to 0·020 for large channels, and he would be inclined to accept it for a canal which is not in such good order, *i.e.*, where the bed is uneven, the value works out to from 0·020 to 0·024.

The Chenab canal is a case where retrogression is going on and there the coefficient would be 0·024. On the whole he would recommend that 0·020 might be taken for canals of large size and in fairly good order. It was safer to adopt a low than a high figure.

Mr. Kennedy would have two values, one for large canals and another for small ones.

Mr. Nethersole.—Kutter's formula is as follows:—

$$V = \left\{ \frac{(41{\cdot}6 + \frac{1{\cdot}811}{N} + \frac{0{\cdot}00281}{S} \sqrt{r}}{\sqrt{r} + N \ (41{\cdot}6 + \frac{0{\cdot}0028}{S}} \right\} \times \sqrt{rs}$$

Mr. Kennedy suggests that the value of N as used in the Punjab, namely, 0·025, is too high,

In the footnote page 5 of Mr. Higham's Tables this is also indicated—he states that in the Punjab canals in good order it is often much less than 0·025 and in a few cases it has been found to be as low as 0·016.

A lower value of N would of course result in a higher value of C in his formula $V = C\sqrt{rs}$.

In the United Provinces the discharges are generally taken by rods which give the mean velocity direct without the application of a coefficient. The standard coefficients used in the case of discharges taken by floats are based on Bazin's formula.

A comparison of the actual coefficient between the mean velocity observed by rods and that observed by floats is generally made at the time of taking the discharges, and in the Northern Division Ganges canal he found that the actual coefficient was very often, in fact generally, higher than that given

in the standard tables. The result of several observations on distributaries carrying from 10 to 200 cusecs showed that it should be increased by from 8 to 12 per cent. Bazin's formula takes cognisance of variations only of the shape of the channel determining *r*, and in the degree of roughness of the perimeter—Kutter takes also the variation of slope into account—but his formula is an extension of Bazin's rather than a correction, and for the range of artificial channels met with in canal practice, the results with 0·025 in Kutter's formula are practically identical with Bazin's, *vide* the preface to Mr. Kennedy's diagrams.

The observations Mr. Nethersole had noted with regard to Bazin's coefficient for earthen channels support Mr. Kennedy's suggestion that 0·025 is too high a value for N and for distributaries, the value suggested by him of 0·0225 which gives an 11 per cent. difference is almost correct. For all distributaries he thought 0·0225 is correct.

Mr. Preston said on the Rakh branch of the Chenab canal which carries a discharge of 1,200 to 1,500 cusecs, he had observations carefully taken which yielded coefficients equivalent to 0·016 and 0·017. The main canal was constructed for a supply calculated with coefficient of 0·025 while the branches were calculated with 0·0225. The bedwidth was estimated to have been 240 feet, but it has been constructed 250 feet, this with 9·5 feet of water and with an assumed coefficient of 0·025 give a calculated discharge of 7,968, the actual discharge observed was, however, 8,320 for a 9·5 feet depth with a 10·8 feet depth an actual dicharge of 10·730 cusecs was obtained which gives a value for N. of 0·018.

His own opinion from the experience he has gained is that 0·020 for large channels is better than 0·0225.

Mr. Kennedy, concluding said the concensus of opinion appears to be that for distributaries or not very large branch canals 0·0225 is the right value to assume and for very large canals 0·020 may safely be taken.

At the end of this sitting Mr. Kennedy referred to his paper on American practice reproduced as*Technical Paper No. 157 and made the following remarks. The objection to the Bear Trap pattern is the cost, and the difficulty of getting the gates to startrising when there is no fall through the weir.

Personally he prefered the Drum weir, and would like to hear the objections to the design on plate XII, he himself saw some objections to the method of fastening and keeping up the shutter, but this could be got over.

The sketch given is not by any means a final design in fact it is 12 or 15 years old.

It is designed to work, not by pressure from above the weir in the river, but from a small reservoir a few feet above the top of the shutter. On Plate IX described on page 17, an idea is given for scouring out bed sand from the head of a canal, without wasting large quantities of water in escapes. It would only come in useful when proper grading to ensure all the sand being carried forward was not possible. There are no such case in the Punjab that he knows of, and they will always be rare. Plate VIII shews an American idea, described at foot of page 16, for only taking in top water, but it assumes an immense amount of surplus water in the river.

Some conversation followed which was not recorded.

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*Not reproduced.

FRIDAY AFTERNOON.

Mr. S. Preston took the chair on Friday afternoon when the following papers were introduced:—

39. Mr. Visvesvaraya's paper on Economy of Water in the Deccan Irrigation.

40. Mr. McLeod's paper on the "Debarred Area" Scheme of the Fatehpur Branch.

41. Mr. Keeling's Gate.

Mr. Leather's paper on Water of the Soil.

Mr. Visvesvaraya opened with a few remarks about the special conditions in Bombay. He said 1 acre of sugarcane required 8 to 10,000 cubic feet of water each watering and as 24 waterings in all are given, 2,40,000 cubic feet are used per acre for sugarcane. Six lakhs of cubic feet in a reservoir will give 2,40,000 cubic feet in the field. The loss has been roughly calculated, and may be taken at 20 per cent. in the lake and the same in each of the canal and distributaries. A duty for sugarcane of 60 acres, at the outlets is obtained. In the case of stored water, many precautions are necessary as it is very expensive. The cost of storing 1 cusec for 8 months is Rs. 10,000 to Rs. 20,000 and including distribution, between Rs. 20,000 and Rs. 30,000.

Mr. Kennedy in discussing the question of the module said it was very expensive; but as sugarcane brings in a revenue of Rs. 40 per acre, the cost of the module would be fully justifiable in Bombay. It is a choice between two evils. Mr. Visvesvaraya did not say his particular model should be adopted, any other that promised to be successful might be tried. Objections have been raised to the module—

(1) that the loss of head through it is too great. No doubt that is so, but the objection does not apply in the Deccan;

(2) cost of renewal of collapsible hose.

This will certainly cause some trouble; but the same material, canvas, is used in pleasure boats and in various other ways and he did not see why it should not be adopted in this instance.

The principles he has described in his note have mostly been followed on works for the past 2 years there have been no complaints from cultivators, while formerly they were frequent.

Formerly on the Nira canal the Engineers considered that they could not mature more than 400 acres of sugarcane, now 800 acres are irrigated easily. The Irrigation Commission said that if the Nira canal could be made to pay 3 per cent. on its capital cost, the greatest objections to spending capital on it would disappear; this percentage has been reached already as the results of working on the lines described in the paper. Two questions in the paper have been raised.

(1) He considered that in the case of a tank, or canal, the supply should be distributed among the cultivators for irrigation and that the Engineer or Revenue Officer should confine his attention to what they do not use.

(2) He knew of many tanks where a supply of water is left at the end of the hot weather and it is practically wasted, as in the hot weather there is very little demand for irrigation. Instead of allowing this water to be wasted he suggested that in April it should be sold for any price it may fetch.

Mr. Nethersole said 20 per cent. evaporation in a storage reservoir seemed very high even if it is throughout the year.

Mr. Preston said evaporation cannot be estimated as a percentage of the volume, it depends mainly upon the water spread.

In the Central Provinces tank projects an allowance of 6 feet on the average water spread has been made. Whether 6 feet is right or wrong may be a matter of opinion; it seems reasonable.

Mr. Kennedy thought it varied from 6 feet to 9 feet.

Mr. Mackenzie said there was a very good chance of getting some reliable figures in a statement he saw the other day. Lately there was no rain from November to March, all through December the level of the reservoir remained steady, so that there was no absorption, the reservoir was 80 feet deep. In January, February and March the level at the top surface of the reservoir was carefully measured and came to 10½ inch for each month; these are dry months; that makes him think 6 feet is not enough.

Mr. Preston was sorry there are no reliable data from the Central Provinces, but arrangements have now been made that most careful statistics should be taken. Not only will tank gauges be erected and read every morning and evening so that the loss by absorption and evaporation can be arrived at for every 24 hours, but rain gauges will be put up somewhere in the catchment area, so that it will be possible to get some idea of the relation between rainfall and runoff. In the Central Provinces there will shortly be some very large tanks and the data it is proposed to collect should be invaluable. With reference to what Mr. Visvesvarya said about the use of all the water in a tank, that is also the view which the Government of India in the Revenue and Agricultural Department hold most strongly. Mr. Preston could not remember what the Irrigation Commission recommended, but was under the impression they hesitated to recommend that the water of one year should be held over on the chance of its being required in the next. Mr. Preston thought the view of the Revenue and Agricultural Department was right because the prosperity the people would derive from the use of the water may help them to tide over possible difficulties in another year while if the water is allowed to remain in the reservoir, perhaps there might be no demand for it the following year.

Mr. G. White said in Jubbulpore and Nagpore reservoir gauges are read every day; in Jubbulpore the loss due to evaporation amounted to ·30 inches a day. At Ajmer there is a tank 25 feet deep and the measurements taken, there showed a loss due to evaporation and absorption of ·30 inches a day also.

Information on the point will be found in the annual reports if any one cares to look for it.

Mr. Davidson said experiments had been made in the Red Hill Tanks, Madras, and the result showed a loss due to evaporation of 6 inches per month, that would be just 6 feet in the year.

Mr. McLeod's paper on the "Debarred Area" Scheme of the Fatehpur Branch.

Mr. McLeod did not think there was much to say beyond what is recorded in the paper; the principle was introduced more or less because there was not a sufficiency of water at the time for the scheme as then proposed. A reference to the Completion Report will explain what was intended and what was actually carried out.

The Fatehpur branch lies entirely to the south of the East Indian railway, and as originally proposed it was intended to irrigate the whole of the country between the East Indian Railway and the Ganges on the north; that idea was abandoned because the percentage of well irrigation was large; in some villages over 40 per cent.; that meant that the canal would be solely a feeder and that the villages through which it passed would have been debarred from irrigation.

The result as finally settled has not been a success; in two parganahs the well irrigation average is only 8 per cent. and in most of the other parganahs it is little or nothing.

In Cawnpore the cultivators appreciate the value of irrigation; they are ready to pay three times the schedule rate provided they get canal water in preference to working wells. Consequently the scheme has been abandoned, it can only be worked to keep out well areas and this would debar whole tracts; to debar whole villages would be difficult because they are intermixed with

the general system of irrigation. It is also an objection that it introduces another form of oppression which it is well to keep clear of.

To some extent the people give the water to land that is protected by wells instead of to dry land. Mr. McLeod thought they would take to their wells again; they reserve wells for special crops.

Mr. Marsh said this system of debarring land from irrigation was introduced with great éclat some 15 years ago and there has been a great deal of correspondence on the subject.

It is impossible to debar plots in villages; after trial it has been decided to give up the attempt to do so.

Mr. Preston said his experience has been exactly the same; in the Punjab it was found impossible to keep water off the well lands. On the Bari Doab canal there used to be a system called *chakabandis* of fixing an area attached to each well and if the cultivator took canal water on any of the fields in these blocks, he was charged unauthorized irrigation rates.

In addition to the usual water, or occupiers, rates, a water-advantage was levied on any field which took canal water in the year. This rate, which varied from Rs. 1-4 an acre at the head of the canal to 8 annas or 12 annas at the tail, was assessed under the Land Revenue Act, not under the Canal Act and as the land attached to a well had already been assessed at wet land revenue rates at settlement, it was held that the water-advantage rate also could not be levied for irrigation on fields included in the well block. This was all extremely complicated and the charge at unauthorized irrigation rates engendered such an enormous amount of ill feeling with the cultivator who never understood the reason for it that long before the assessment system was altered the practice of charging it was abandoned.

In the new projects recently submitted for sanction, Mr. Benton has proposed that no irrigation at all should be given in a considerable area traversed by one of the canals, on the grounds that the tract is already sufficiently protected by wells and that it is a better policy to conserve the water for dry tracts in which well irrigation is impossible. Mr. Preston thought this was perfectly sound; there can in his opinion be no objection to refusing irrigation to entire tracts which are sufficiently protected by wells, but it is most unadvisable to refuse it to individual fields and needlessly worries the people. He was glad this was being given up in the United Provinces.

Mr. Bion explained that on the Eastern Jumna canal they drew up what they called "oserbandis" or time tables showing when each channel was open and that the only way in which the principle could be got to work was by the cultivators acting as a check on each other.

Mr. Keeling's gate.

Mr. Preston explained the working of the gate, and asked Mr. Davidson if he could add to the information on the subject. He did not know that he could add very much to what Mr. Preston had said. They contemplate building some high dams in Madras in which they will have to work sluices under very big heads. Stoney is not prepared to guarantee his gate for any head over 130 feet at the outside. Keeling designed this gate for use at a much lower level. He had received a tender from an English firm for its construction and the cost for a discharge of 3,000 cusecs works out to £10,500. It is of course so far only a design and has not been tried.

Stoney's gates are very satisfactory for the heads of pressure for which they have been designed.

Mr. Mackenzie said the gate looked complicated, but was not really so and he dilated on the technical and engineering features of the scheme.

As regards the expense he said a gate to work under a great head cannot be got for nothing, whatever kind of sluice is used it will cost a good deal. A sluice to work under a head of 150 feet cannot be compared with a low pressure sluice which is a comparatively simple thing. The expense of the gates is a trifle when added to the cost of a large dam. He thought there would

be a considerable demand in the near future for storage works in Madras and Bombay; and the question of obtaining a satisfactory gate to work under large heads is a serious question and he would like to see some of the gates which are already in the market tested practically.

Mr. Nethersole preferred the principle adopted at the Assouan dam in Egypt.

Mr. Benton thought that before this gate is adopted a great deal more should be known about it and this seemed to be the opinion of those present.

Mr. Preston then said it only remained for him to bring this Conference to a conclusion, he had not prepared a set speech and had no intention of making one. He hoped that all have felt that the trouble they have been put to in coming so far has been repaid by the intercourse which they have had with one another.

Looking through the papers which have been considered he was certain all would acknowledge the great value of the large shutters which are designated Smart's shutters. He had not the slightest doubt that, as he remarked before the consideration of the design at this meeting will bear fruit not only in the Punjab, but elsewhere and that in the near future large shutters of at least 40 feet span would be introduced. What the ultimate limit of size will be it is difficult to say; for himself he does not altogether see the advantage of the 80 feet span which Mr. Mackenzie dreams of, and he felt rather inclined to think 50 feet will prove to be a workable, or necessary, maximum.

There had been a very interesting discussion on the design for the Suketar superpassage, and the meeting is certainly indebted to Mr. Hill for the very valuable papers that he has contributed.

He thought that upcounty Engineers had come to the conclusion that Mr. Visvervaraya's module would not be of much use to them due to the loss of head through it and to the cost: the circumstances in Bombay are different, as Mr. Visvervaraya had pointed out at the present sitting. Personally he (Mr. Preston) did not think the first cost was of any particular matter. The loss of head which would be necessary would certainly be an objection to its use upcountry while the repairs, on Mr. Visvesvaraya's own showing, would be considerable.

Mr. Visvesvaraya had said that the life of the hose which had been humorously called the "concertina" would be only three months, in Mr. Preston's opinion this is very much against the design. Modules are not required by ones and twos, but by thousands and to repair thousands of "concertinas" every three months would be rather a big order.

Personally he did not think there is very much to be made out of lift irrigation by machinery at present. A lift installation has recently been started on the Chenab canal by Lala Ganga Ram, who has recently retired from the Public Works Department. Government has given him a considerable concession of land, and he is lifting water, not from wells and the subsoil, but from a canal; he has been given a tract of land the level of which is something like 6 to 7 feet above the canal water surface; that is his maximum lift, but he has got an inexhaustible supply of water from the canal, and lift irrigation in these circumstances may perhaps do well, especially as he is charged reduced rates for the water.

He thought the outcome of the discussion on Mr. Marsh's paper on the automatic puddling of channels was that every one was more or less in accord. Before the discussion he was under the impression there would have been more difference of opinion as the design of the canal which he had passed round is very different to anything heretofore constructed.

The difference of opinion reduced itself to a question of decimals of a foot and on the whole there was general unanimity on the subject.

Mr. Preston was glad to find from several of the papers that Engineers have not been afraid to confess their failures. It is a trite saying that more is learnt from failures than from successes, but anyone criticising these

proceedings will not be able to say that the Engineers assembled to blow their own trumpets or that they have been afraid to publish their mistakes.

He would like to thank the gentlemen of the different provinces who have sent up the excellent models.

In conclusion the President thanked Mr. Stanley, the Secretary of the Conference, and Mr. Burbridge, the Superintendent of the Irrigation Branch Office, on whom a good deal of the burden of the arrangements had fallen, for their services and by request of the members of the Conference presented them with pencil cases as a memento.

Mr. Benton desired to say a very few words. Many suggestive papers and papers on improvements of designs had been presented and he thought all had derived the greatest advantage from them and especially from the discussion that ensued; great benefit had also been derived from hearing the experiences of men working in other parts of the country and in the interchange of views in conversations outside the meeting. Mr. Preston did not wish to take the credit for initiating the Conference, but he was sure he was expressing the feelings of all present when he said they thanked him very much for the opportunity he has given them of meeting.

G. I. C. P. O.—No. 574 R & A., C. W.—13-6-1905—650—R. T. C. D.